CALIFORNIA REGIONAL $PM_{10}/PM_{2.5}$ AIR QUALITY STUDY 1995 INTEGRATED MONITORING STUDY DATA ANALYSIS

SPATIAL REPRESENTATIVENESS OF MONITORING SITES AND ZONES OF INFLUENCE OF EMISSION SOURCES

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ABSTRACT

This report is a contribution to the California Regional $PM_{10}/PM_{2.5}$ Air Quality Study, 1995 Integrated Monitoring Study. It examines the spatial representativeness of particulate matter (PM) monitoring sites, characterizes sites by their types of emission-source influences, and evaluates the zones of influence of emission sources on PM concentrations. Daily measurements of PM_{10} mass and chemical composition were obtained for the period 1 through 14 November 1995 from a saturation monitoring network around Corcoran, California, and for varying portions of the period 9 December 1995 through 6 January 1996 for three saturation monitoring networks around Bakersfield, Fresno, and the Kern Wildlife Refuge, California. The Corcoran, Bakersfield, and Fresno networks each included one core site, situated at a pre-existing monitoring location, with more extensive and more temporally resolved measurements, and 12 to 25 additional sites, located throughout monitoring areas of about 300 to 800 km^2. The data were interpolated and spatial gradients were evaluated for PM_{10} mass, the sum of organic and elemental carbon, the sum of secondary species (sulfate, nitrate, and ammonium), and the sum of crustal species. Spatial gradients were used to evaluate the spatial representativeness of each monitoring site and the zones of influence of emission sources. Additional analyses of the zones of influence were carried out by using a dispersion model and by computing a series of regression relationships between concentrations and emissions densities averaged over a range of spatial scales. Spatial representativeness varied considerably among sites, days, and PM components. Monitoring sites generally had greater areas of representativeness for secondary species than for PM_{10} mass, and lesser areas for crustal and carbon components. It was shown that at least 90 percent of each saturation monitoring domain would exhibit concentrations within 20 percent of those of the core site plus one or two additional sites. The most representative combinations of two to three sites were identified for each domain. While the core sites were shown to represent average domain concentrations well, they did not always represent the network maxima. Neighborhood-scale (about 1 km), urban-scale (about 15 to 20 km), and regional-scale (exceeding about 20 to 25 km) zones of emission influences were identified during both fall, in the Corcoran network, and winter, in the other networks. During winter, the neighborhood and urban scales dominated, with a mean urban background concentration of approximately 40 $\mu g\ m^{-3}$ in the Fresno and Bakersfield networks and mean peak-site values of about 60 to 80 $\mu g\ m^{-3}$. During fall, the mean regional background in the Corcoran network was about 100 $\mu g\ m^{-3}$, with neighborhood- and urban-scale influences increasing mean concentrations at the peak sites to about 130 to 190 $\mu g\ m^{-3}$.

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GLOSSARY

ARB	Air Resources Board
CAR	Sum of PM_{10} elemental and organic carbon
CMB	Chemical mass balance
CO	Carbon monoxide
CRU	Sum of PM_{10} crustal components
DRI	Desert Research Institute
HNO_3	Nitric acid
kg	kilogram
km	kilometer
IMS95	Integrated Monitoring Study, 1995
INPUFF	Gaussian Integrated Puff model
NO_x	Oxides of nitrogen
PCA	Principal components analysis
PM	Particulate matter
PMT	PM_{10} mass
PR	Population representativeness
QA	Quality assurance
SEC	Sum of PM_{10} secondary species (sulfate, nitrate, ammonium)
SR	Spatial representativeness
UTM	Universal Transverse Mercator
$\mu g\ m^{-3}$	microgram per cubic meter

EXECUTIVE SUMMARY

INTRODUCTION

This report is a contribution to the California Regional $PM_{10}/PM_{2.5}$ Air Quality Study, 1995 Integrated Monitoring Study. It documents findings resulting from Task 4.2.1, "Spatial Representativeness of Sites", and Task 4.5.6, "Evaluating the Zone of Influence of Emissions."

OBJECTIVES

The objectives of Task 4.2.1 are:

- Describe aerosol and precursor species sampling sites and their surroundings.
- Classify the spatial scale of sites (neighborhood to regional) and site types (agricultural to industrial).
- Evaluate the adequacy of the monitoring networks for representing human exposure, maximum particulate (PM) concentrations, and source influences.

The objectives of Task 4.5.6 are:

- Compare source contributions from each identifiable source category among nearby measurement locations.
- State and justify conclusions about the zone of influence of each source type relative to the components that influence PM concentrations.

APPROACH

The following approach was followed to evaluate the spatial representativeness of sites for Task 4.2.1:

a. Prepare work plan.
b. Obtain, compile, and check data.
c. Verify site-type classifications through examination of gridded data files, provided by the ARB, covering emissions, land use, population, and wind fields.

d. Use graphical techniques and principal components analysis (PCA), coupled with comparison of results to gridded wind and emission fields, to delineate groups of sites covarying in response to particular emissions source areas and meteorological conditions.
e. Generate gridded concentration fields from the ambient measurements, delineate and visually inspect the temporal and spatial patterns, and determine the spatial representativeness of each monitoring location through analysis of gradients in the gridded concentration fields.

The following approach was followed to evaluate the zones of influence of emissions for Task 4.5.6:

a. Prepare work plan.
b. Review estimates of sites' spatial scales of representativeness (from Task 4.2.1) and estimate downwind distances over which concentrations at source-dominated sites are attenuated to regional background values.
c. Compare site concentrations with gridded emission estimates at various spatial scales.
d. Use a dispersion model to estimate the boundaries of upwind zones of influence of emissions affecting specified monitoring locations.
e. Compare diurnal variations of PM concentrations to diurnal profiles of emission activities, daily emission activities, and meteorological variables.

TECHNICAL FINDINGS

The IMS95 was spatially extensive but temporally limited. The data may reflect meteorological and other conditions specific to the sampling period. The conclusions of this report are therefore specific to the study period, and their applicability to other time periods is not known.

Sampling and Measurements

The IMS95 saturation networks and core-site sampling produced a rich and informative data base. Overall, the measurements of PM mass and chemical composition were of reasonably high quality and consistency. However, because complete speciation was not carried out on some samples, it was not always possible to conduct some standard data validation tests, such as comparison of mass to the sum of species concentrations. Time series plots and spatial contour plots were used to supplement the standard validation tests.

The measurements were spatially dense but temporally limited, which limited the utility of some statistical procedures, such as principal components analysis, which require a large number of temporal replicates.

The comparison of measurements from collocated samplers captures sampling error as well as analytical error. Only two saturation sites were collocated. For most species, the uncertainties calculated from the differences between these two collocated sites were considerably higher than the analytical uncertainties listed in the data base.

Portable saturation samplers were collocated with the core-site sequential-filter samplers at Bakersfield, Fresno, Kern, and Corcoran. When the 3-hour measurements from the sequential-filter samplers were aggregated to match the 24-hour sampling intervals of the saturation monitors, the agreement was very good. No offsets were evident and few substantial deviations between the saturation and core samplers occurred.

Classification of Site Characteristics

Three sites were located west of the western boundary of the IMS95 modeling domain (North Los Banos, Panoche Water District, and Candelabra Tower in Walnut Grove). The site designations of the other 81 chemistry sites were compared to information in the gridded land use, population, and emissions files, and to photos and videos of the sites. The sites' primary and secondary designations, which were made at the inception of the sampling program, were based upon emission source types and included the principal categories of agricultural, urban, transportation, residential, rural, industrial, and boundary, as well as numerous subcategories. For 57 of the sites, one or more items of conflicting information were found.

For 18 sites, emission source values in the gridded emissions inventory conflicted with the designated site characteristics. However, in only one case, confirmed by inspection of videos and photos, was the primary designation of the site apparently incorrect. For each of the remaining cases, site photos and videos indicated that the immediate environs of the site were of the same type as its classification. However, in each of these cases, emissions within the 4 km x 4 km cell containing the site in question were not dominated by the designated source type and were in fact substantially different than the emissions mix associated with other sites of the same designated type.

In addition, for thirty of the 42 residential or industrial sites, emissions within either a 4 km x 4 km or a 20 km x 20 km area were dominated by transportation or agricultural sources, rather than residential or industrial sources. However, as noted above, site photos and videos indicated in each case that the immediate environs of each such site were of the same type as its classification.

For ten other cases, some potential emission sources were observed in the videos or the photos, but had not been included among the secondary characteristics of the sites.

Thirty one (31) sites had designated characteristics that conflicted with the gridded land use files. In most cases, the land use was defined as agricultural, but the site characteristic was residential or urban. Inspection of photos and videos suggested that, in most cases, the land use files were inaccurate, of too coarse a resolution, or possibly outdated. As noted above for the emissions files, in some cases the site photos and videos indicated that the immediate environs of each such site were of the same type as its classification, though the larger surrounding area may have been different.

Fourteen (14) sites had designations that conflicted with the gridded population files. For 7 of these 14, the population appeared too small for a residential site. For the remaining seven sites, which were classified as either agricultural or industrial, the population appeared too large. The photos and videos again supported the existing site designations, suggesting that the gridded population file warrants investigation.

Site classifications, which were based on visual characterizations of site surroundings, did not predict emission source strengths on larger distance scales (4 to 20 km), which were found to be more characteristic of emission zopnes of influence. However, the site classifications were a useful indication of potential local emission sources, which in some cases were substantial.

Spatial Representativeness of the Monitoring Sites

The spatial representativeness (SR) of a monitoring site may be loosely defined as the area within which pollutant concentrations are approximately constant. The more explicit definition that was used in this study is the percentage of the area of a saturation monitoring domain having concentrations within 20 percent of those recorded at the site under consideration. Population representativeness was defined as the percentage of domain population in areas having concentrations within 20 percent of those recorded at the site under consideration. The choice of 20 percent was based upon consideration of differences that would be expected to be judged significant from a health-effects perspective, the variation of concentrations across monitoring sites, measurement uncertainty, and an analysis of the sensitivity of the findings. Typically, PM concentrations varied across sites by about 50 percent on any day while sampling uncertainty for PM_{10} mass was about 10 $\mu g\ m^{-3}$, corresponding to about 10 to 20 percent of the typical mass concentrations recorded in the Fresno and Bakersfield areas.

To determine spatial representativeness, the monitoring data were interpolated to fine (0.1 km) grids for both the fall and winter saturation networks. The species analyzed were PM_{10} mass, the secondary component (sum of sulfate, nitrate, and ammonium), carbon (elemental plus organic), and the crustal component (the sum of aluminum, silicon, iron, manganese, calcium, and magnesium). The gridded values were then used to determine the portions of the monitoring domains having values within the specified percentage of those recorded at each individual site.

Spatial representativeness varied considerably among sites, days, and components. Averaging across days, the mean areal fractions of the saturation domains having PM_{10} concentrations within 20 percent of those recorded at the core sites were 65% for Bakersfield, 87% for Corcoran, 44% for Fresno, and 79% for Kern. Taking into consideration the areas of each monitoring domain, these values correspond to 195 km^2 for Bakersfield, 626 km^2 for Corcoran, 352 km^2 for Fresno, and 134 km^2 for Kern. In terms of distance, the values roughly correspond to about 10 to 20 km for the three winter networks and about 25 km for the fall Corcoran study. As noted, considerable variation occurred among days and chemical species. Moreover, some sites, other than core sites, exhibited values representative of much smaller areas.

Population representativeness was always slightly greater or approximately equal to area representativeness. Monitoring sites generally had greater areas of representativeness for secondary species than for PM_{10} mass, and lesser areas for crustal and carbon components.

It was shown that at least 90 percent of each saturation monitoring domain would exhibit concentrations within 20 percent of those of the core site plus one or two additional sites. The most representative combinations of two to three sites were identified for each domain. While the core sites were shown to represent average domain concentrations well, they did not always represent the network maxima. In Corcoran, the maximum site exhibited PM mass concentrations up to 130 $\mu g\ m^{-3}$ greater than those of the core site. In Bakersfield and Fresno, the differences in concentration between the core and the maximum sites were less than 5 $\mu g\ m^{-3}$ on average.

Zones of Influence of Emissions

Three methods were employed to evaluate the zones of influence of emissions. First, gridded concentration fields were examined to identify concentration gradients. The gradients were qualitatively evaluated to identify approximate distances over which concentration peaks diminished to both urban and regional background levels. The gridded concentration fields were also compared with maps of emission densities. Second, a series of regressions of site concentrations versus emissions densities were carried out. Emission densities were determined for a variety of scales of spatial averaging and the averaging scales that provided the best fits between concentrations and emissions were identified. Finally, a dispersion model was used to estimate upwind areas of influence on the core sites.

The three methods yielded consistent results. The contour plots revealed neighborhood-scale (on the order of 1 km) influences in the Corcoran domain and urban-scale (5 to 15 km) influences for all saturation networks. In the fall Corcoran study, gradients of PM_{10} mass were 10 to 50 $\mu g\ m^{-3}\ km^{-1}$, implying that nearby emission sources often influenced site concentrations substantially. The distance scale for the decay from peak to urban background values was about 5 to 10 km in Corcoran and 10 to 15 km in the other domains. However, the range of influence of emission sources could have been greater than these scales since the network domains were not large enough to capture the decay from urban background levels to regional background levels.

The regression results indicated that transport and dispersion of emissions occurred on a scale of about 15 km (urban scale) during winter and about 40 km (regional scale) during fall. Local influences (neighborhood scale, 0.5 to 4 km) could have been superimposed upon the urban and regional-scale dispersion, as indicated by the scatter of concentrations within each saturation network, but the regressions were not capable of discerning such influences since the emissions grid-cell resolution was only 4 km x 4 km. The winter regressions are also consistent with regional dispersion of PM emissions on scales exceeding 15 to 20 km, since correlation coefficients remained high for scales exceeding the 14 km scale of the best fit regressions. The fall regression results showed no correlation between concentrations and emissions densities at scales less than 20 km because the urban sites (in Fresno and Bakersfield) showed lower PM_{10} concentrations than did the Corcoran sites, even though emission densities were greater in the urban areas. On a scale of about 40 km, though, the Corcoran concentrations were associated with higher emission densities, thus indicating the contribution of a regional background concentration to the overall values observed at the Corcoran sites.

The dispersion model calculations for the winter episodes showed substantial source influence for locations within less than 5 to about 15 km of receptor sites and less influence, but geographically more widespread, from locations within about 15 to greater than 25 km. The results suggest a scale of significant emissions influence of a few up to about 15 km, and a scale of approximately 20 km or more over which emissions are more widely dispersed but still contribute to general background levels. Input data for the dispersion calculation were unavailable for the fall period.

In summary, it is possible to identify neighborhood-scale (about 1 km), urban-scale (about 15 to 20 km), and regional-scale (exceeding about 20 to 25 km) emission influences during both fall and winter. During winter, the neighborhood and urban scales dominated, with a mean urban background concentration of approximately 40 $\mu g\ m^{-3}$ in the Fresno and Bakersfield networks and mean peak-site values of about 60 to 80 $\mu g\ m^{-3}$. During fall, the mean regional background in the Corcoran network was about 100 $\mu g\ m^{-3}$, with neighborhood- and urban-scale influences increasing mean concentrations at the peak sites to about 130 to 190 $\mu g\ m^{-3}$.

Other Findings

In the winter study, diurnal profiles of emissions, ambient concentrations, and chemical mass balance (CMB) source strengths showed generally consistent patterns (during fall, only 24-hour samples were collected). Evening peaks in PM mass coincided with both the afternoon decrease in mixing height and the late afternoon and early evening increases in motor vehicle emissions and fuel combustion.

At all four winter core sites (Bakersfield, Fresno, Chowchilla, and Kern), $PM_{2.5}$ mass was about 75 percent of the PM_{10} mass, on average. The $PM_{2.5}$ carbon and secondary (nitrate plus ammonium plus sulfate) concentrations were 80 to 100 percent of the PM_{10} carbon and secondary concentrations.

Both PM_{10} and $PM_{2.5}$ mass were dominated by the carbon and secondary components; however, the temporal patterns of carbon and secondary species differed. At all sites, secondary-species concentrations showed a daytime rise (averaging about

5 to 15 $\mu g\ m^{-3}$). Bakersfield and Fresno showed mean evening rises of particulate carbon of about 30 $\mu g\ m^{-3}$. At Bakersfield and Fresno, secondary concentrations exceeded carbon concentrations during the day; carbon exceeded secondary at night. As a result, at Bakersfield and Fresno, both PM_{10} and $PM_{2.5}$ mass concentrations began to rise at about 3:00 p.m. (the 1500-1800 sample) and reached maxima between 1800 and midnight. The evening peaks in mass at Bakersfield and Fresno were driven by the carbon component. At Kern and Chowchilla, the secondary components also showed daytime peaks, but dominated during all hours. Consequently, at Kern and Chowchilla, PM mass peaks occurred during the day.

Organic carbon concentrations exceeded elemental carbon by factors of 2:1 to 3:1. At each site, both elemental and organic carbon followed the same diurnal profile, but the profiles at the urban sites (Bakersfield and Fresno) differed from those at the rural sites.

Regression analyses showed high correlations between particulate carbon and both CO and soluble potassium. These correlations were interpreted as indicating that motor vehicles and fuel combustion were the principal sources of particulate carbon, with the latter source being slightly larger. CMB analyses also allocate particulate carbon to motor vehicles and combustion, though a nontrivial fraction of organic carbon was unexplained by the CMB source contributions. The relative amounts of the carbon allocated to motor vehicles and combustion by the multiple regression and the CMB analyses were approximately consistent with emission inventory estimates.

Factor analysis was used to delineate chemical species that tended to covary. While the number of samples was limited, three distinct groups of species were delineated. Elemental and organic carbon were associated with CO, NO_x, alkenes (ethylene and acetylene), and aromatics (benzene, m-xylene, p-xylene). The second species group included C2-C5 alkanes (ethane, propane, i-butane, n-butane, i-pentane, n-pentane), and the third group included species having a photochemical source (formaldehyde, acetaldehyde, and acetone). Alkane concentrations were substantially greater at Bakersfield than at Fresno, with the ratio of ethane-to-acetylene being about 3:1 at Bakersfield and 1:1 at Fresno.

RECOMMENDATIONS FOR FUTURE MONITORING STUDIES

Sample Collection and Measurements

Many aspects of the IMS95 sample collection and analysis should be retained for a future, expanded study, while a few should be re-examined. The portable saturation samplers performed well and yielded measurements that agreed well with collocated sequential filter samplers. Also, the design of the saturation domains generally yielded good estimates of the spatial patterns of the ambient concentrations. In a future study, though, the numbers of samplers and the dimensions of the networks should be reconsidered. In the Corcoran area, additional sites located around the industrial area would help to better define the steep concentration gradients observed there. In Bakersfield, no monitors were located south of the area having the highest emission density. All saturation domains were large enough to observe decreases from peak concentrations to urban background, but not to regional background levels.

In a future study, it would be desirable to develop a data-analysis plan prior to sampling. The questions to be addressed by the saturation networks might include revisiting those addressed by the present study as well as other questions of interest. The data-analysis plan could then be used to guide the design of the saturation networks. Results from the present study suggest expanding the spatial dimensions of the networks, as indicated above; to reduce the sampling requirements, it may be possible to reduce the density of monitoring sites in some areas. Although this study did not determine the effects of reduced density of sampling, it would be possible to do so by reviewing the contour plots carefully and recomputing some of them by leaving out some of the more closely spaced sites. The data analysis plan should also specify the temporal duration of sampling. A more detailed study might commence in November and continue through January with saturation monitors operating continuously. However, both the temporal and spatial extent of sampling should be determined by the data-analysis methods to be used, taking into consideration the costs of sampling and analysis.

The time series of measurements clearly indicate the value of daily sampling, as opposed to sampling at intervals of three or six days. Longer-sampling intervals potentially miss the PM peaks. The 24-hour sample duration provided a good temporal resolution without requiring massive numbers of samples. However, complementing the 24-hour samplers with the more detailed 3-hour resolution from the sequential filter samplers at the core sites added useful insights. The addition of 3-hour, fine and coarse size resolution at the Corcoran site would be a valuable enhancement.

As indicated earlier, data validation could be more effective if all or most sites collected samples that were speciated and if more collocated samplers were employed.

Modeling

While the present project did not focus on PM modeling, it nevertheless made use of a number of the gridded modeling files, through comparison of grid-file information to photos and videos, and some issues appear to warrant further examination. First, the western boundary of the IMS95 domain would need to be shifted westward to encompass several monitoring sites, which had been established because they were considered critical for establishing boundary conditions. Second, the accuracy and resolution of the emissions, population, and land-use files should be reviewed. Discrepancies between site photos and videos, on the one hand, and the gridded values for population, land-use type, and emissions type, on the other, suggest the existence of considerable sub-grid scale variability. The importance of such variability for the accuracy of modeling predictions appears to warrant consideration. In addition, the accuracy of some values, such as the locations of major point sources in the Corcoran area, should be reviewed.

Compliance Monitoring

The results obtained from the saturation networks have implications for PM compliance monitoring. The core sites in the Bakersfield and Fresno domains obtained maxima close to the network-wide maxima. However, because substantial percentages of those two domains often exhibited concentrations differing from those at the core sites by more than twenty percent, accurate estimation of network-wide outdoor PM exposure requires two to three sites in addition to the core site of each domain. In contrast, the Corcoran core site obtained values representative of much of the Corcoran area on all days but one; however, the domain maximum, which was highly localized, usually exceeded the core site value by substantial amounts.

SECTION 1: INTRODUCTION

OBJECTIVES

This report documents findings resulting from Task 4.2.1, "Spatial Representativeness of Sites", and Task 4.5.6, "Evaluating the Zone of Influence of Emissions." The objectives of Task 4.2.1 are:

- Describe aerosol and precursor species sampling sites and their surroundings.
- Classify the spatial scale of sites (neighborhood to regional) and site types (agricultural to industrial).
- Evaluate the adequacy of the monitoring networks for representing human exposure, maximum particulate (PM) concentrations, and source influences.

The objectives of Task 4.5.6 are:

- Compare source contributions from each identifiable source category among nearby measurement locations.
- State and justify conclusions about the zone of influence of each source type relative to the components that influence PM concentrations.

APPROACH

The following approach was followed to evaluate the spatial representativeness of sites for task 4.2.1:

a. Prepare work plan.
b. Obtain, compile, and check data.
c. Verify site-type classifications through examination of gridded data files, provided by the ARB, covering emissions, land use, population, and wind fields.
d. Use graphical techniques and principal components analysis (PCA), coupled with comparison of results to gridded wind and emission fields, to delineate

groups of sites covarying in response to particular emissions source areas and meteorological conditions.

e. Generate gridded concentration fields from the ambient measurements, delineate and visually inspect the temporal and spatial patterns, and determine the spatial representativeness of each monitoring location through analysis of gradients in the gridded concentration fields.

The following approach was followed to evaluate the zones of influence of emissions for Task 4.5.6:

a. Prepare a work plan.
b. Review estimates of sites' spatial scales of representativeness (from Task 4.2.1) and estimate downwind distances over which concentrations at source-dominated sites are attenuated to regional background values.
c. Compare site concentrations with gridded emission estimates at various spatial scales.
d. Use a dispersion model to estimate the boundaries of upwind zones of influence of emissions affecting specified monitoring locations.
e. Compare diurnal variations of PM concentrations to diurnal profiles of emission activities, daily emission activities, and meteorological variables.

OVERVIEW OF REPORT

The report documents findings for both Tasks 4.2.1 and 4.5.6. Section 2 contains a summary of the data and an evaluation of data precision, accuracy and uncertainty. Section 3 contains an evaluation of site characteristics. The use of principal components analysis is described In Section 4. Section 5 presents our findings on the spatial representativeness of sites in the IMS95 network. The analysis of zones of influence of emission sources is presented in Section 6. Section 7 contains an analysis of diurnal concentration variations. Our conclusions regarding site characteristics, site representativeness, and zones of influence are presented in Section 8. The appendices show a selection of the contour plots and other data displays that were generated and examined.

SECTION 2: DATA SUMMARY AND EVALUATION

OBJECTIVES

Data that were used to complete Tasks 4.2.1 and 4.5.6 are described below. These data were reviewed for accuracy, precision and uncertainty, and corrections were made when necessary and feasible.

DATA REQUIREMENTS

The data that were used are:

- Data and other site-related files from ARB:
  - Mass and chemical concentrations at core, boundary, and saturation sites, level 2 validated
  - Site location and classification files
  - Photos, site drawings, and electronic maps of areas around sites
  - Hourly temperature, relative humidity, wind speed, wind direction
- Gridded files from ARB (4 km resolution):
  - Land use
  - Population
  - Emissions
  - Wind fields
- Other information
  - Results of CMB analyses

In the course of working with the data, we identified several data-quality questions and made corrections when feasible. Our findings are documented below.

DATA REVIEW

Gridded Files

In the population file and the emissions summary files, the IMS95 cell coordinates were offset by one unit in both the horizontal and vertical directions. Corrections were made in our files. We also obtained corrected emission files from the ARB.

Meteorological Data

Mixing heights were obtained both from the IMS95 modeling files and from a concurrent data-analysis effort conducted by T&B Systems. In some cases, the mixing heights determined by T&B Systems from the Bakersfield and Fresno soundings were substantially different from those that had been obtained from the diffusion break calculation of the IMS95 meteorological model. The two principal differences were: (1) T&B Systems specified low (50 - 100 m) nighttime mixing heights, whereas the meteorological model often estimated mixing heights of several hundred meters at night, and (2) T&B Systems selected the lower-elevation temperature inversion if two were evident, whereas the meteorological model appears to have selected the stronger inversion. For consistency, we have used the T&B Systems mixing heights throughout all later analyses.

Chemical Concentration Files

We obtained the chemical-concentration data files that were current as of July 1997. The files were in "normalized" format, which means that each row contains a parameter label (e.g., PM10 mass), a value (or "result"), an uncertainty, and two QA columns, "*qcflag*" and "*rawflag*". The *result* column was set to -99 to indicate missing data. Since the only *result* value that was less than zero denoted a missing value, we defined a new flag variable called "*resflag*", which was set to V (for valid) whenever the *result* was greater than or equal to zero and to I (for invalid) whenever the *result* is less than zero.

For the whole fall and winter data set, there are 320 distinct parameters (e.g., PM_{10} mass, PM_{10} mass uncertainty, etc.). For these 320 parameters, Table 1 shows the following counts: 77% of the qcflags are missing, 13% are valid, and 87% of the resflags are valid (i.e., result $\geq$ 0).

Table 1. Summary counts of combinations of QA flag codes for all data (320 parameters, all sites, and all days).

qcflag	rawflag	resflag	count	qcflag	resflag I	resflag V
	0	I	3511		3511.00	
	0	V	92089			92089.00
	7	I	112		112.00	
	7	V	3208			3208.00
	8	I	1907		1907.00	
	8	V	209			209.00
	9	I	576		576.00	
	9	V	32	77.91%		32.00
0		V	5131			5131.00
0	0	V	12148	13.24%		12148.00
6	6	V	586	0.45%		586.00
8	8	I	432	0.33%	432.00	
9	0	I	10530	8.07%	10530.00	
		TOTALS:	130471	100.00%	13.08%	86.92%
						100.00%

We next restricted the data base to 51 parameters of particular interest to us. These parameters include the following species: mass, secondary inorganic species (sulfate, nitrate, and ammonium), crustal components (silicon, aluminum, calcium, magnesium, iron, and manganese), and carbon (elemental and organic). For each, we include backup-filter values (if any), concentrations and uncertainties, and all size fractions. Table 2 shows the summary counts of QA flags. Again, a large proportion (79.5 percent) of the qcflag variable was missing.

Table 2. Summary counts of combinations of QA flag codes for 51 parameters (all sites and all days).

qcflag	rawflag	resflag	cnt	qcflag	resflag I	resflag V
	0	I	1916		1916	
	0	V	25256			25256
	7	I	22		22	
	7	V	836			836
	8	I	558		558	
	8	V	100			100
	9	I	150		150	
	9	V	24	79.54%		24
0		V	1492			1492
0	0	V	3212	12.96%		3212
6	6	V	22	0.06%		22
8	8	I	112	0.31%	112	
9	0	I	2586	7.13%	2586	
		TOTALS:	36286	100.00%	14.73%	85.27%

Table 3 shows an analysis for the 18 parameters to be used in subsequent analyses of the saturation networks: mass, carbon (elemental, organic, total, and backup filters), secondary species (sulfate, nitrate, ammonium (2 measurements), backup-filter nitrate), and crustal compounds (aluminum, silicon, iron, manganese, calcium, magnesium). Only size=T and 24 hour duration are included (the saturation samplers did not collect shorter-duration samples or the fine fraction). Only 26% of the qcflags are zero (valid) and 60% of the qcflags are missing. Both valid and invalid resflags occur in cases where rawflag is 0 (valid), 7 (suspect), 8 (invalid), and 9 (missing). Using only qcflag=0 would greatly restrict the available data. Therefore, we used samples where either rawflag or qcflag=0 and resflag=V. As shown in the last column, this selection criterion captures 74% of the data without including any overtly invalid samples.

Table 3. Summary counts of combinations of QA flag codes for 18 parameters (all sites and all days).

qcflag	rawflag	resflag	cnt	qcflag	resflag I	resflag V	(rawflag=0 or qcflag=0) and resflag=V
	0	I	779		779	0	0
	0	V	4683		0	4683	4683
	7	I	12		12	0	0
	7	V	58		0	58	0
	8	I	232		232	0	0
	8	V	52		0	52	0
	9	I	64		64	0	0
	9	V	12	60%	0	12	0
0		V	793		0	793	793
0	0	V	1798	26%	0	1798	1798
8	8	I	64	1%	64	0	0
9	0	I	1293	13%	1293	0	0
			9840	100%	24.84%	75.16%	73.92%

After eliminating invalid or suspect data according to the procedure described above, the data were reviewed further. For later analyses, we computed the following groups of variables in both the PM_{10} and $PM_{2.5}$ fractions: (1) the sum of organic and elemental carbon ("CARBON"), (2) secondary species (sulfate, nitrate, and ammonium) ("SECONDARY"), and (3) crustal species (aluminum, silicon, iron, calcium, magnesium, and manganese) ("CRUSTAL"), (4) the sum of CARBON, SECONDARY, and CRUSTAL (SUM). (CARBON and CRUSTAL did not include the estimated mass of oxygen or other species associated with organic carbon and soil-derived elements). For all cases, SUM was very close to the sum of all species and averaged about 25 to 30% less than PM mass, as expected, since CARBON and CRUSTAL did not include the mass of oxygen, water, and hydrocarbon constituents. However, some samples showed suspiciously large deviations. Two cases of obviously incorrect data were identified. First, some measurements from site B01 for January 6 were clearly incorrect, as was seen by comparing them with data from the collocated site B12:

Jan 6:	B01	B12
CARBON	8.6	30.1
CRUSTAL	5.7	6.2
SECONDARY	9.1	39.9
SUM	23.4	76.2
PM10	95.9	78.5

The second incorrect value was the PM10 mass at site F30 on January 6, which had a PM_{10} value of 164.7 and a SUM of 74.4. The PM_{10} concentration was approximately 50% greater than any other Fresno site on that date. A list of suspect data was provided to the ARB and the listed samples were investigated by DRI. The two samples noted above were invalidated and four others were marked as suspect:

OBS	YEAR	MONTH	DAY	SITE	PMT	SUM	DIFF	ERROR	PCTDIFF
10	1995	12	26	F31	97.7	50.9	46.8	7.9	47.9
11	1995	12	26	K15	48.5	23.9	24.6	5.0	50.6
12	1995	12	27	B07	69.3	34.0	35.3	6.3	50.9
13	1995	12	27	F30	107.7	53.9	53.8	8.7	49.9

Revised data bases were to be posted in the San Joaquin data archives. We made the noted changes in our existing data files, so as to permit proceeding with our analyses in a timely manner.

DATA PRECISION AND ACCURACY

Graphical Data Displays

Graphical and statistical analyses were used to identify data anomalies and to qualitatively understand relationships among sites and between sites and their surroundings.

We obtained the most recent Level 2-validated data. Since complete chemical speciation was not carried out at all locations or dates, some of the standard Level-2 tests would not have been carried out for all samples. Thus, these comparisons of measurements among sites may help provide another level of data validation. We generated and examined a large number of time series plots and spatial displays. A subset of plots is presented here, along with discussion and preliminary conclusions.

There are four saturation regions, Corcoran, Fresno, Kern, and Bakersfield. Corcoran was operated 1-14 November 1995. The other three were operated from 9 December 1995 to 6 January 1996. We analyzed four PM10 entities, which we refer to as *PMT*, *CRU*, *SEC*, and *CAR*. *PMT* is PM10 mass, and is the variable denoted "mass" for size fraction "T" in the data sets. *CRU* is crustal PM10 mass, which is the sum of aluminum, calcium, magnesium, manganese, silica, and iron. *SEC* is secondary PM10 mass, and is the sum of nitrate, ammonium, and sulfate. Finally, *CAR* is carbon PM10 mass, which is the sum of elemental and organic carbon.

Simultaneous time series present a general picture of the overall pattern and variability within each saturation region. They also show data that bear looking into for being much larger or smaller than the bulk of measurements in the region. Contour plots represent the spatial relationship between sites and the gradients between them.

The time series of PMT measurements for all Corcoran saturation sites from 1-14 November is shown in Figure 1. Site C05 stands out as consistently high. Sites C18 and C12 show large variability, coming out both high and low across the time series. Figures 2-4 show CRU, CAR, and SEC. Of interest is the relatively smaller variability among sites in SEC compared with the variability of PMT and CRU. This effect is consistent with greater dispersal and mixing of secondary pollutants associated with their long time of formation and long residence time.

Site C05 is very close to the regional median for SEC, while it is well above for

CRU and CAR. Measurements of CRU, CAR, and SEC were not made on the samples from C12 and C18. The high PMT and CRU values at C05 are consistent with its location along the railroad tracks in the industrial section of Corcoran. The description memo for C05 reads, "Eastern city boundary, cotton staging area//On northern end of cotton staging area. On southwest side of grain elevators. Site between cotton staging area and core site." Site C06, approximately 1 km north of C05, is also on the rail line, but not adjacent to the cotton staging area.

For our initial review of the data, we used a $1/r^2$-interpolation method to generate gridded values with grid spacing of 1 x 1 km from the measurements taken at the saturation sites. We then drew contour plots from the 1 x 1 km gridded values. Figure 5 shows a contour plot of the Corcoran area on November 13, while Figure 6 shows a more limited contouring region, including C05. An important caveat needs to be noted here: while the 1 x 1 km gridding provides sufficient resolution over most of the area shown, it is too coarse where the sites are closely located, e.g., around sites C04, C05, C06, C10, C12, C15, and C16. For example, the highest measurement value was about 290 μg/m3 (at C05), but the interpolation generated a high value of 239 $\mu g/m^3$ at the center of the grid cell containing C05 (because it averaged the values from C05, C16, C12, and other nearby sites). Thus, while these displays suffice for qualitatively examining the spatial patterns of the data, a finer interpolation grid is used in later tasks.

Figure 7 shows the PMT time series for all Fresno saturation sites from 9 December to 6 January. No single site stands out as did C05 in Corcoran, although F30 has notably high values on January 5 and 6. The value for F30 on January 6 was investigated further (see earlier discussion) and was subsequently invalidated. The appearance of Figure 7 hints at a bimodal distribution on some days, with a cluster of higher concentration data and a cluster of lower concentration data. Figures 8,9, and 10 show the available CRU, CAR, and SEC data. F30 does not show the January 6 peak that is apparent in PMT. Intersite variability again appears less for SEC than for CRU and CAR, although less strikingly than for Corcoran. Figure 11 shows contours of the $1/r^2$-interpolated grid for Fresno PMT on January 6. The sharpest gradients are, not surprisingly, around F30 (whose measurement was later invalidated). Figure 12 shows a similar display for December 26, on which there was a lot of variability, but no extreme values. On both December 26 and January 6, the highest concentrations (usually exceeding 100 $\mu g/m^3$) occurred in the central portion of the domain, encompassing sites F20, F21, F41, and F31 (except for the peak at F30 on January 6, which was later invalidated).

Figure 13 shows the time series for Kern PMT data from December 9 to January 6. There is low variability, as would be expected of a small area remote from most sources. The only high outlier is K17 on January 2. Two low outliers are K17 on December 28 and K16 on January 3. Only K15 had complete speciation, and, at that site, time series of CRU, SEC, and CAR indicate that most of the PMT is secondary (about 16 to 35 μg/m3) with lower contributions from CAR (about 5 to 7 μg/m3) and CRU (about 2 μg/m3).

Figure 14 shows the time series for Bakersfield PMT data. Variability appears somewhat lower than for the other regions. Two outliers are B10, which is low on December 19 and B02, which is high on January 2. Figure 15 is the PMT time series for the two collocated Bakersfield sites, B01 and B12. Agreement is generally good, but there are several instances of considerable difference. Since agreement should be consistently good for two collocated samplers, the presence of a few larger deviations should serve as a warning that some of the deviations among locations may be artifacts and not genuine spatial gradients.

Overall, the time series and spatial displays indicate that the Level II measurements are of reasonably high quality and consistency. We flagged as suspect some of the samples explicitly identified above. For example, flags were assigned to isolated, low concentrations, such as at K17 on December 28, which could not be easily explained. The higher PM values at C05 were not flagged, since the consistently higher concentrations of CRU and CAR, but not SEC, at C05 suggest that the observed maxima there represent real influences from a strong, local source. Since we could not prove or disprove the accuracy of most of the flagged measurements, they were generally included in subsequent analyses. However, we attempted to verify that our results were not driven by suspect samples.

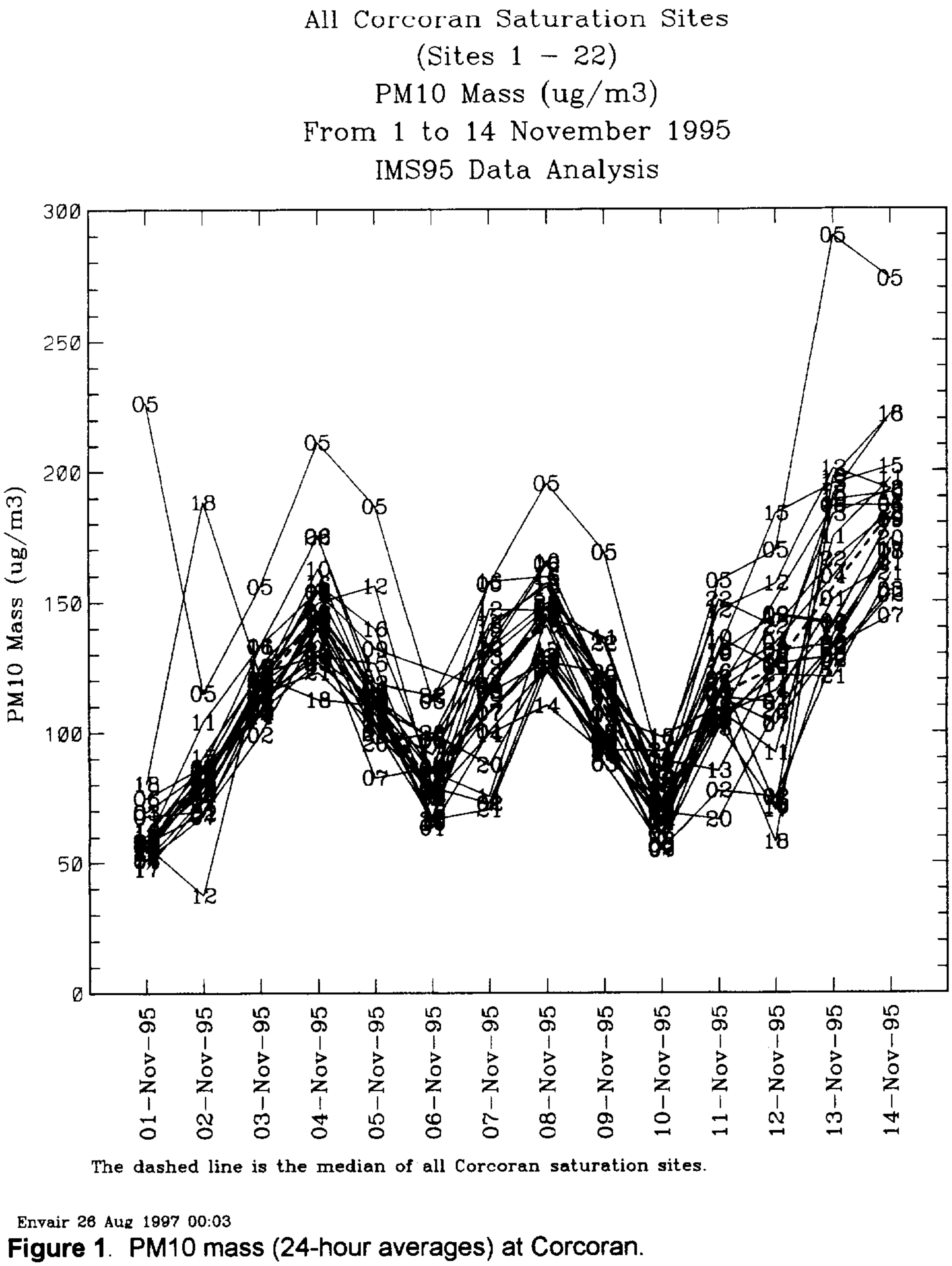


Figure 1. PM10 mass (24-hour averages) at Corcoran.

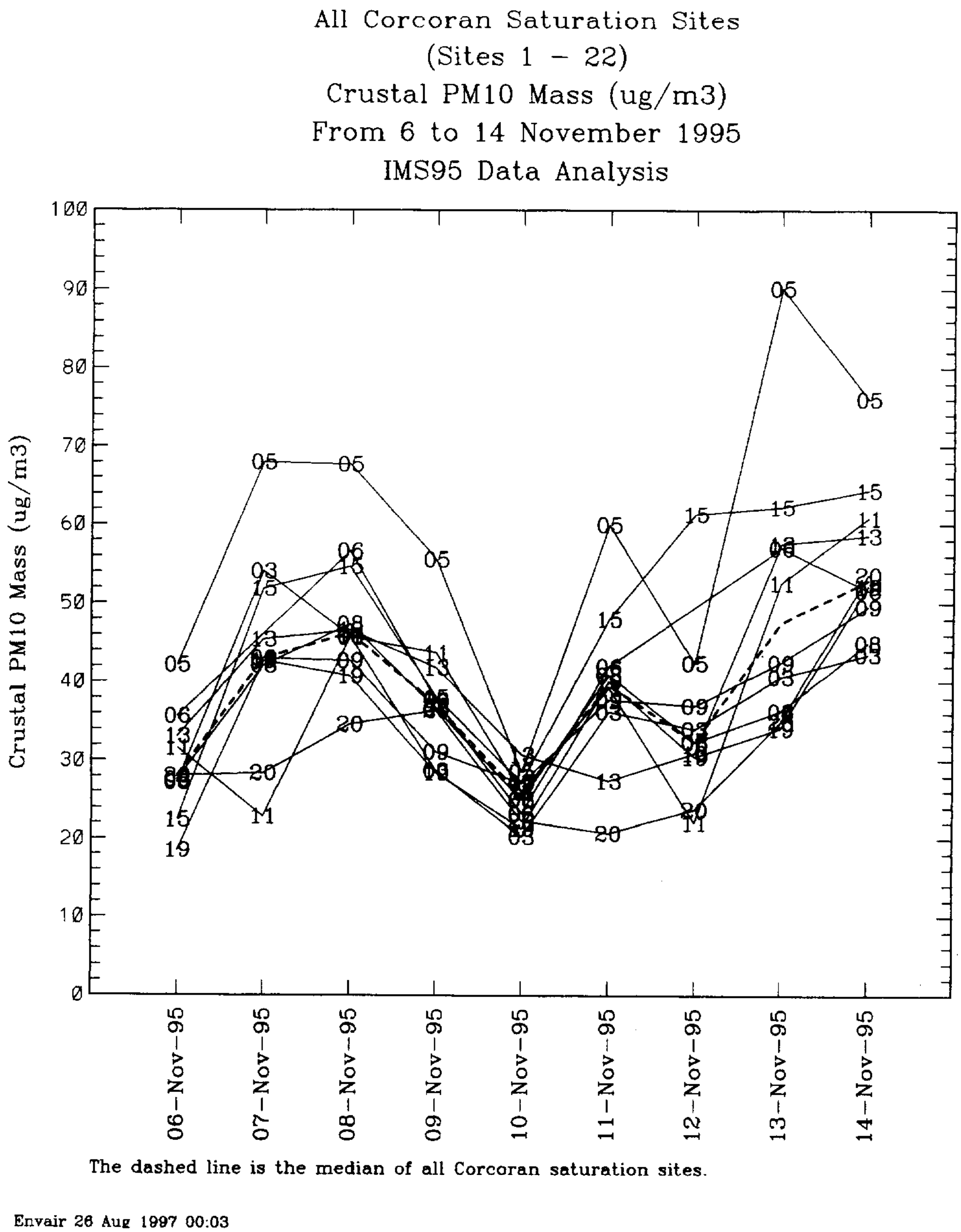


Figure 2. Mass of PM10 crustal species at Corcoran saturation monitoring sites.

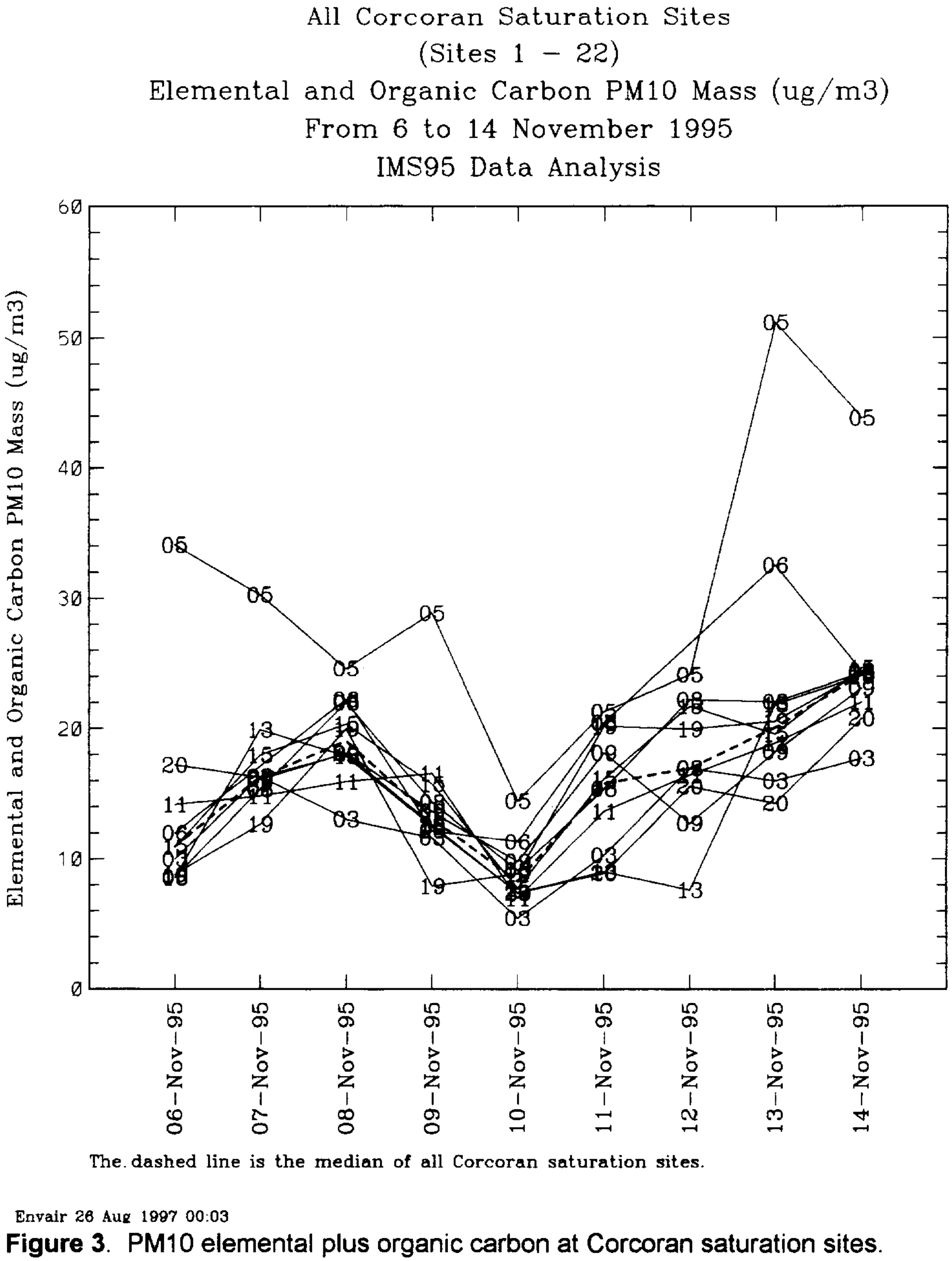


Figure 3. PM10 elemental plus organic carbon at Corcoran saturation sites.

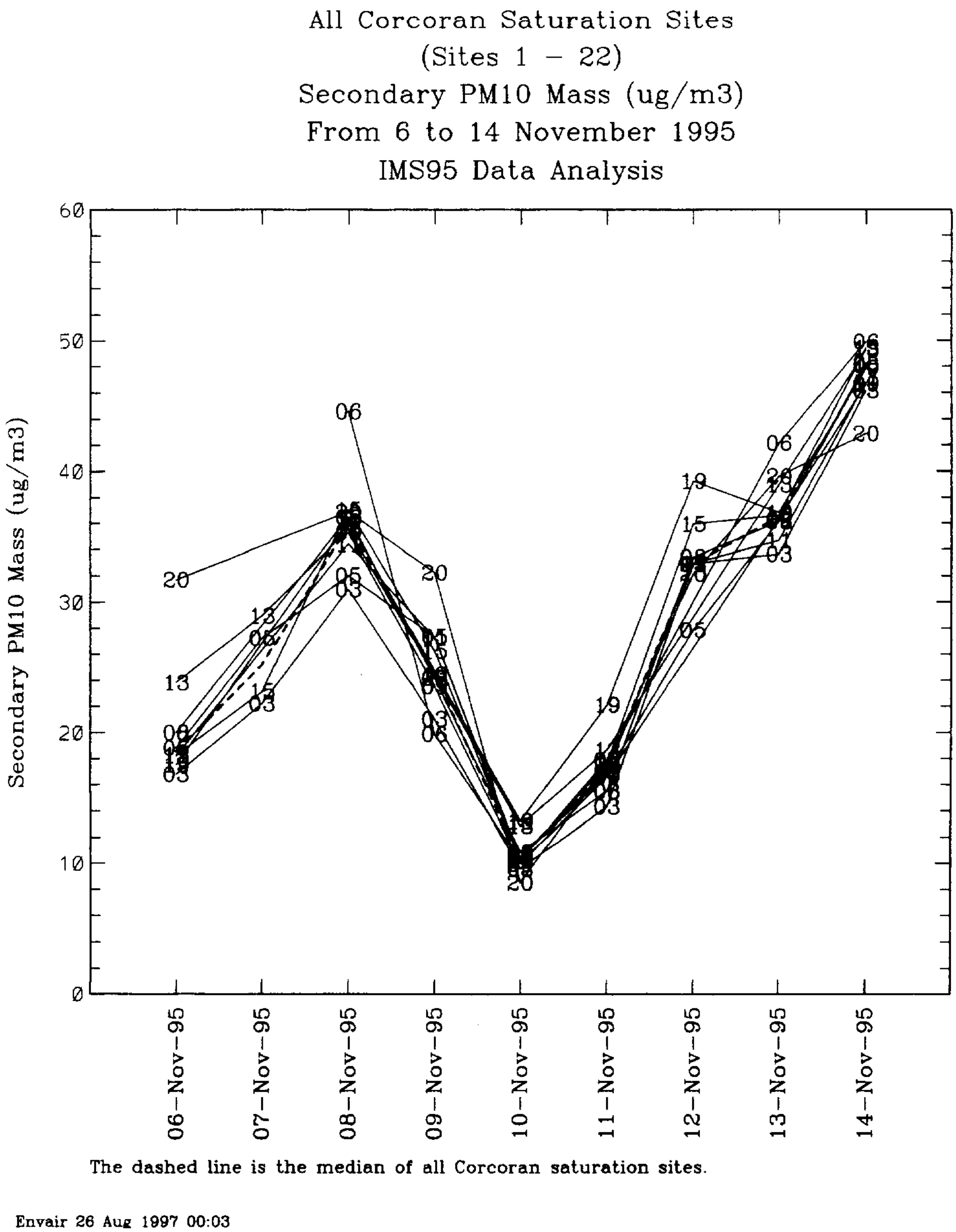


Figure 4. PM10 secondary species at Corcoran saturation sites.

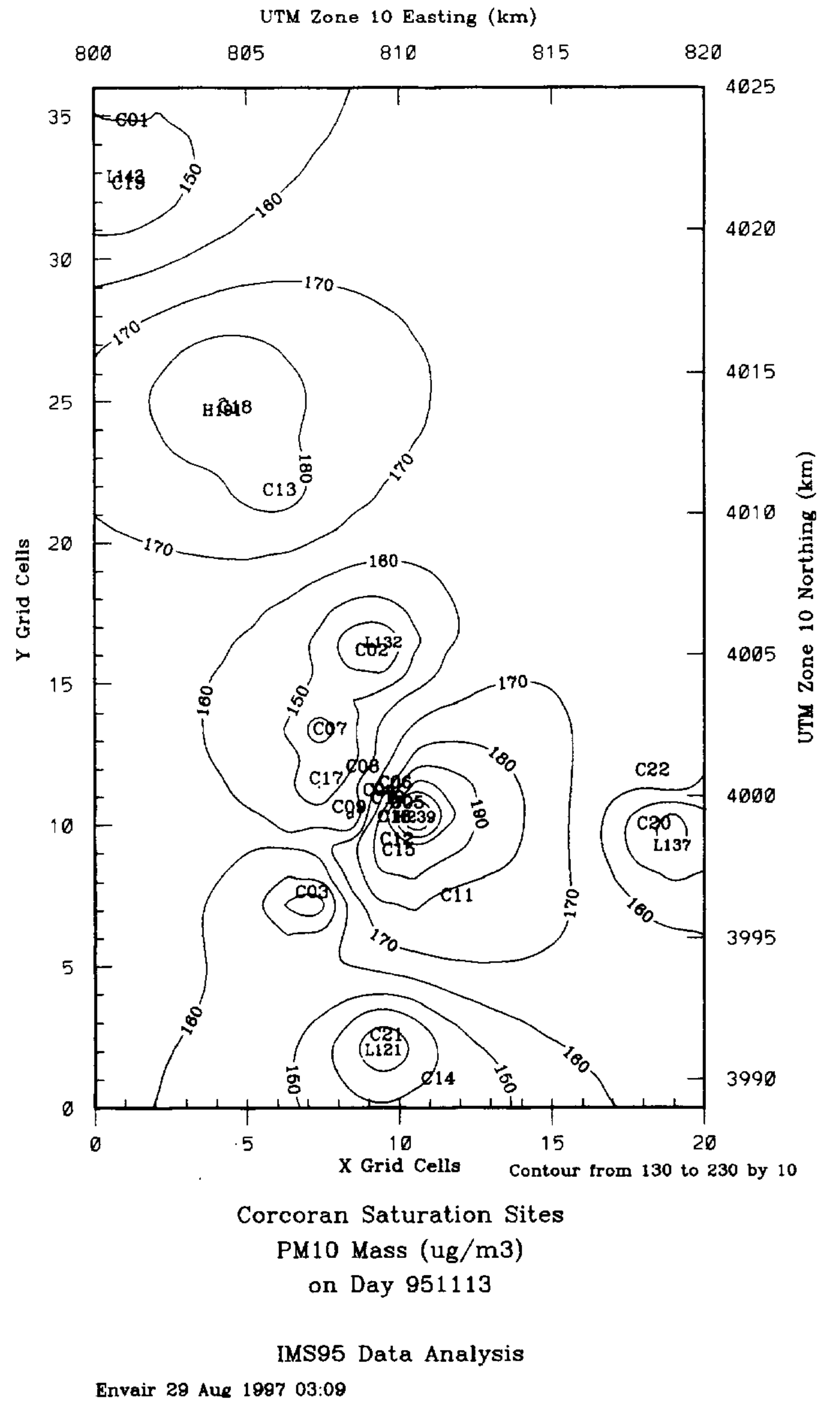
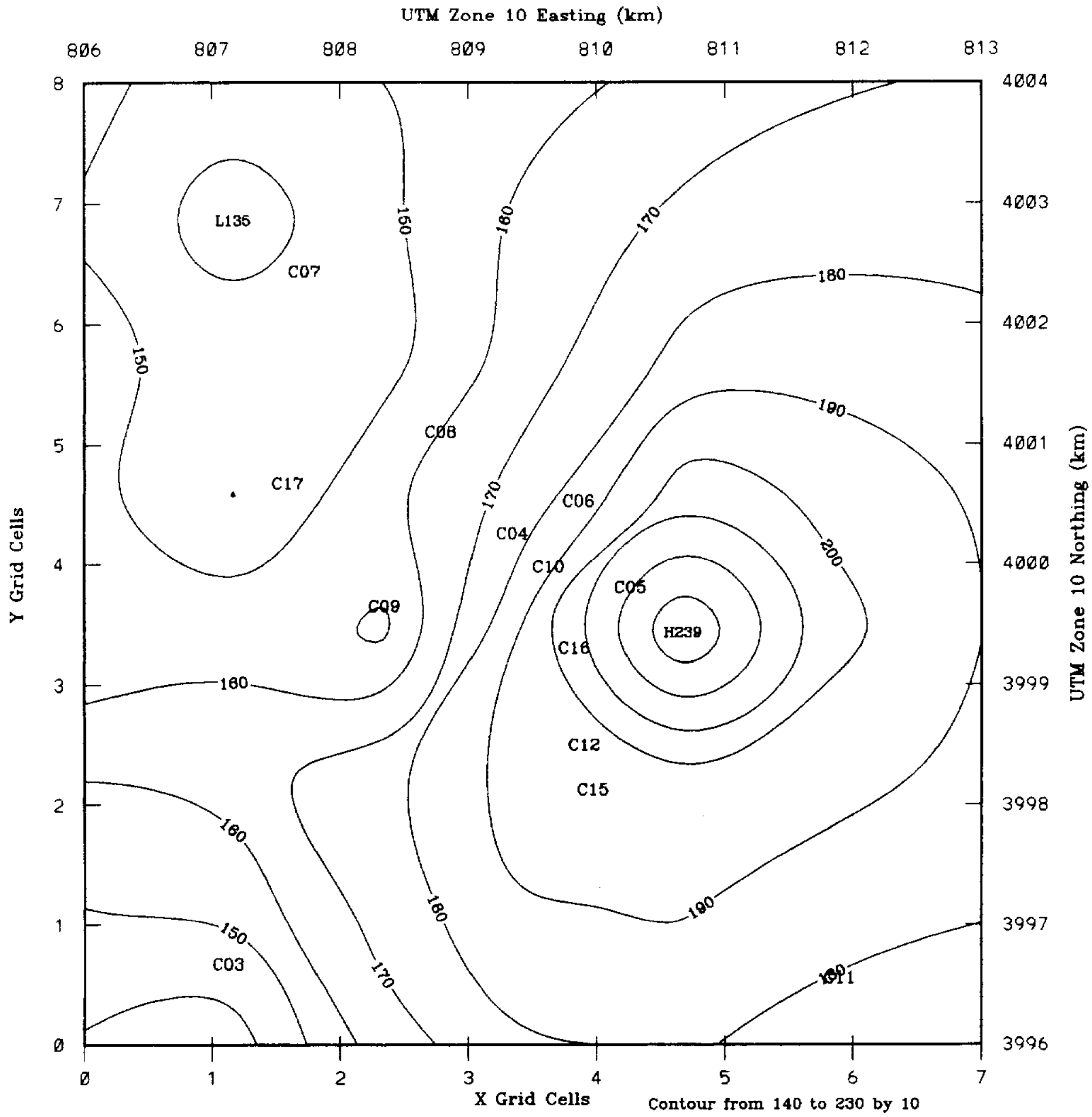


Figure 5. Contour plot of PM10 mass on November 13, 1995, at all Corcoran saturation sites.



Corcoran Saturation Sites
PM10 Mass (ug/m3)
on Day 951113

IMS95 Data Analysis

Envair 29 Aug 1997 09:49

Figure 6. Contour plot of PM10 mass on November 13, 1995, subset of Corcoran saturation sites.

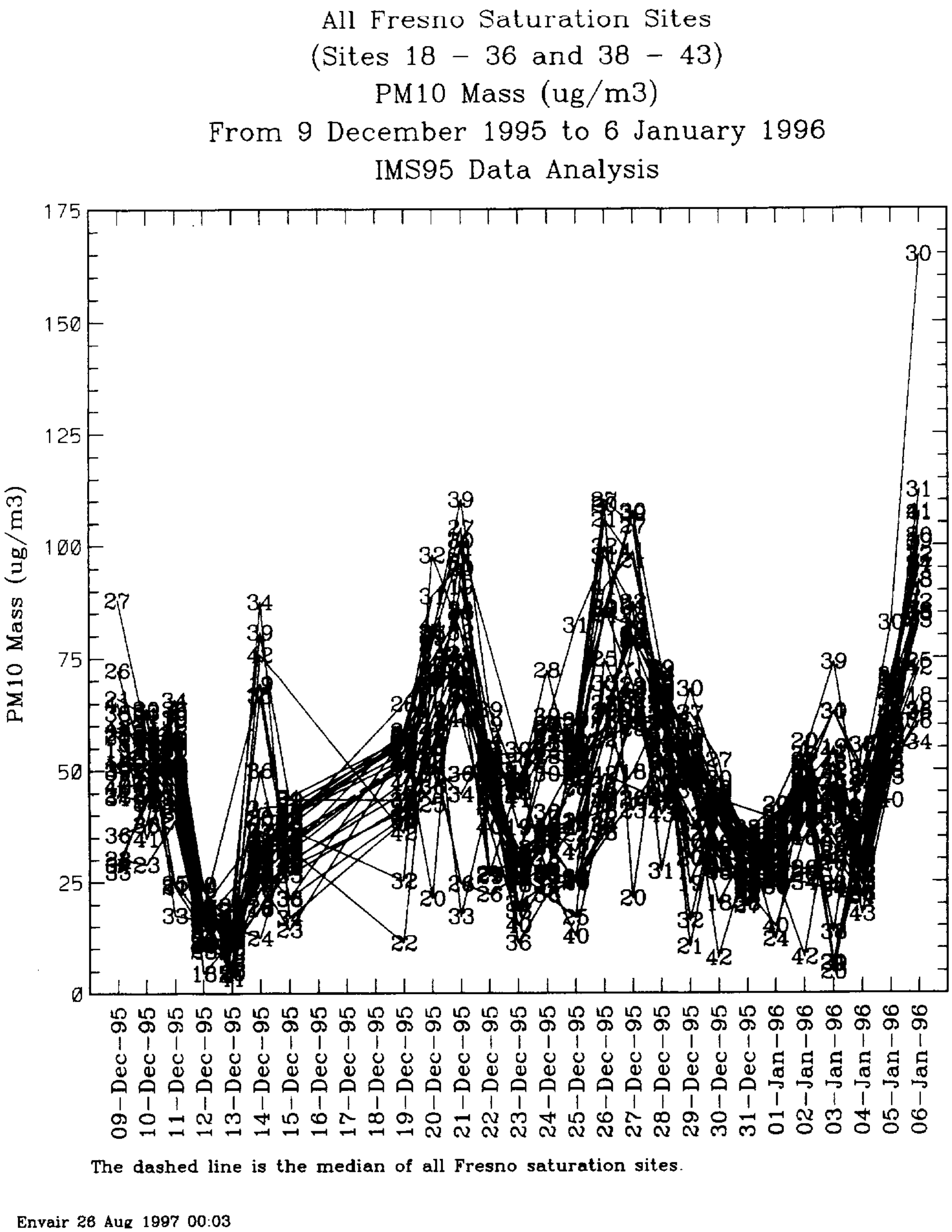
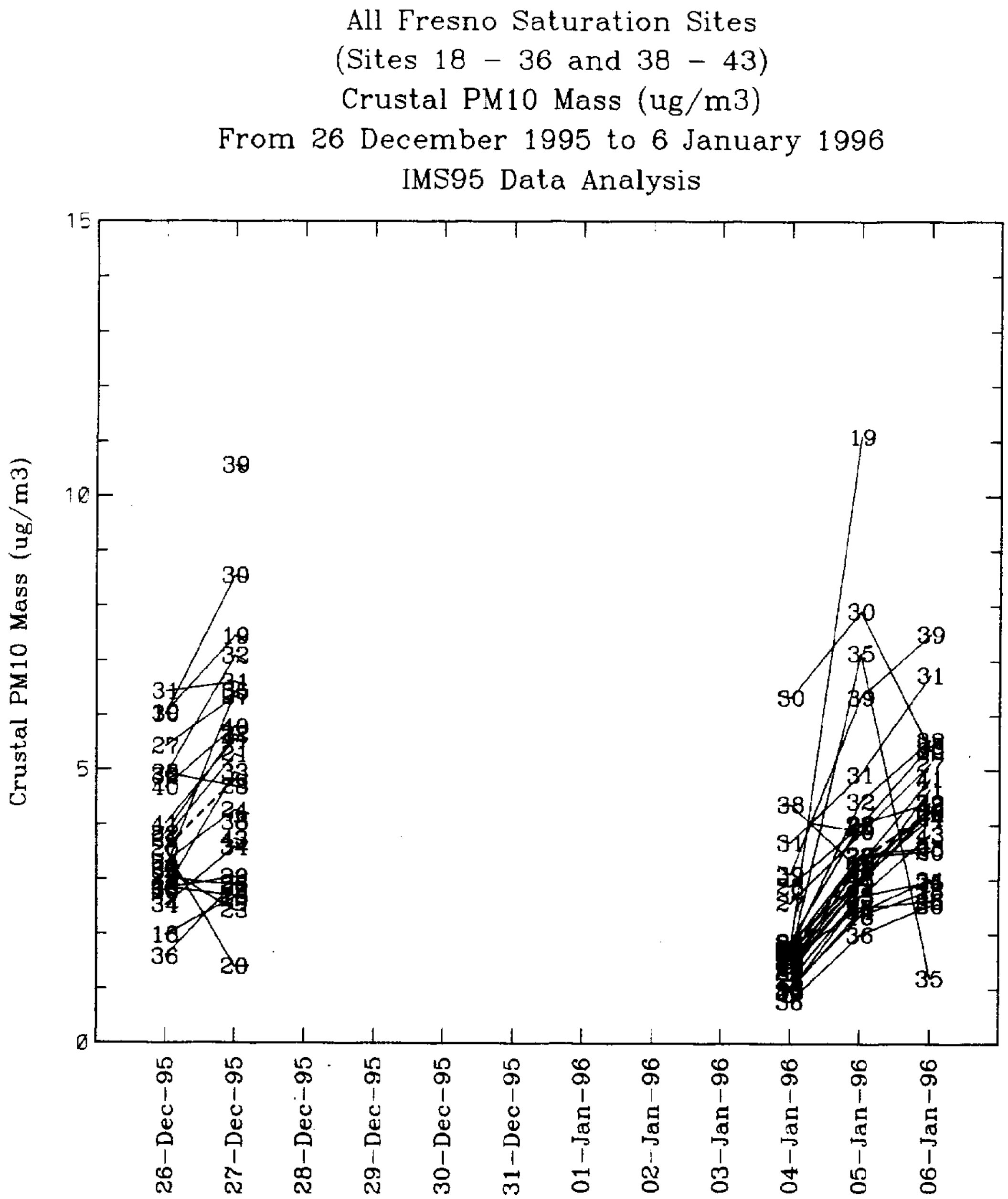


Figure 7. PM10 mass at Fresno saturation sites.



The dashed line is the median of all Fresno saturation sites.

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Figure 8. PM10 crustal species at Fresno saturation sites.

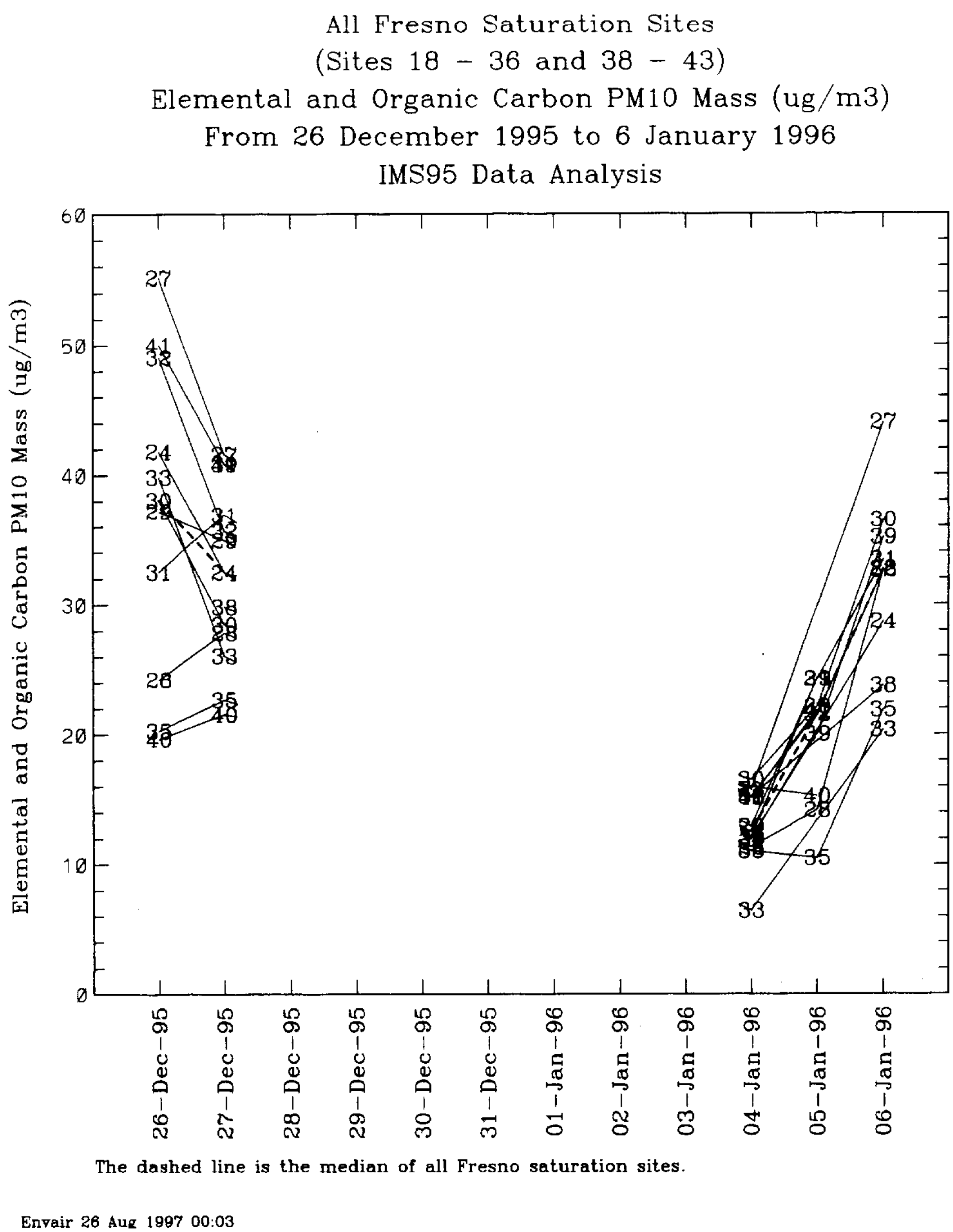


Figure 9. PM10 elemental plus organic carbon at Fresno saturation sites.

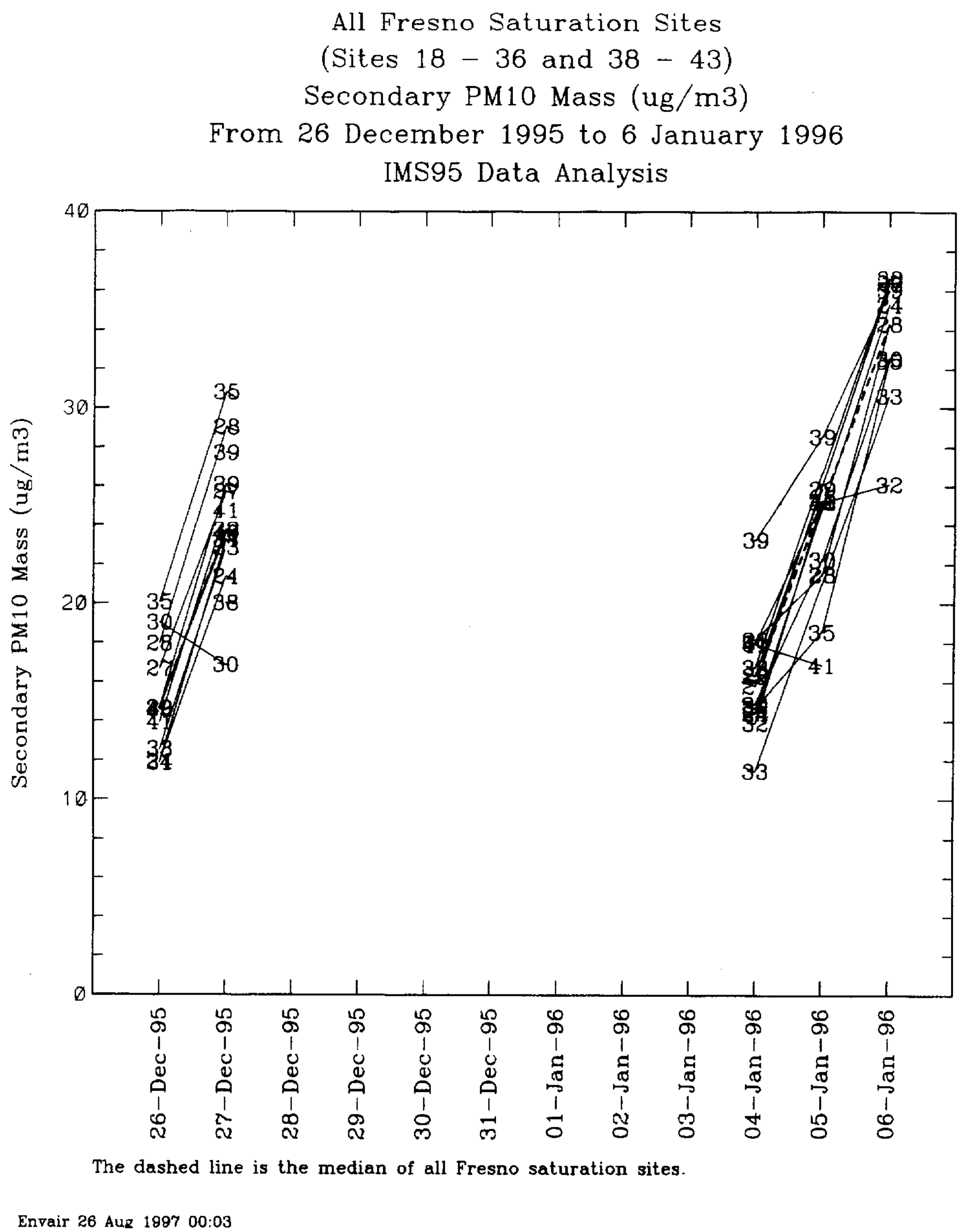
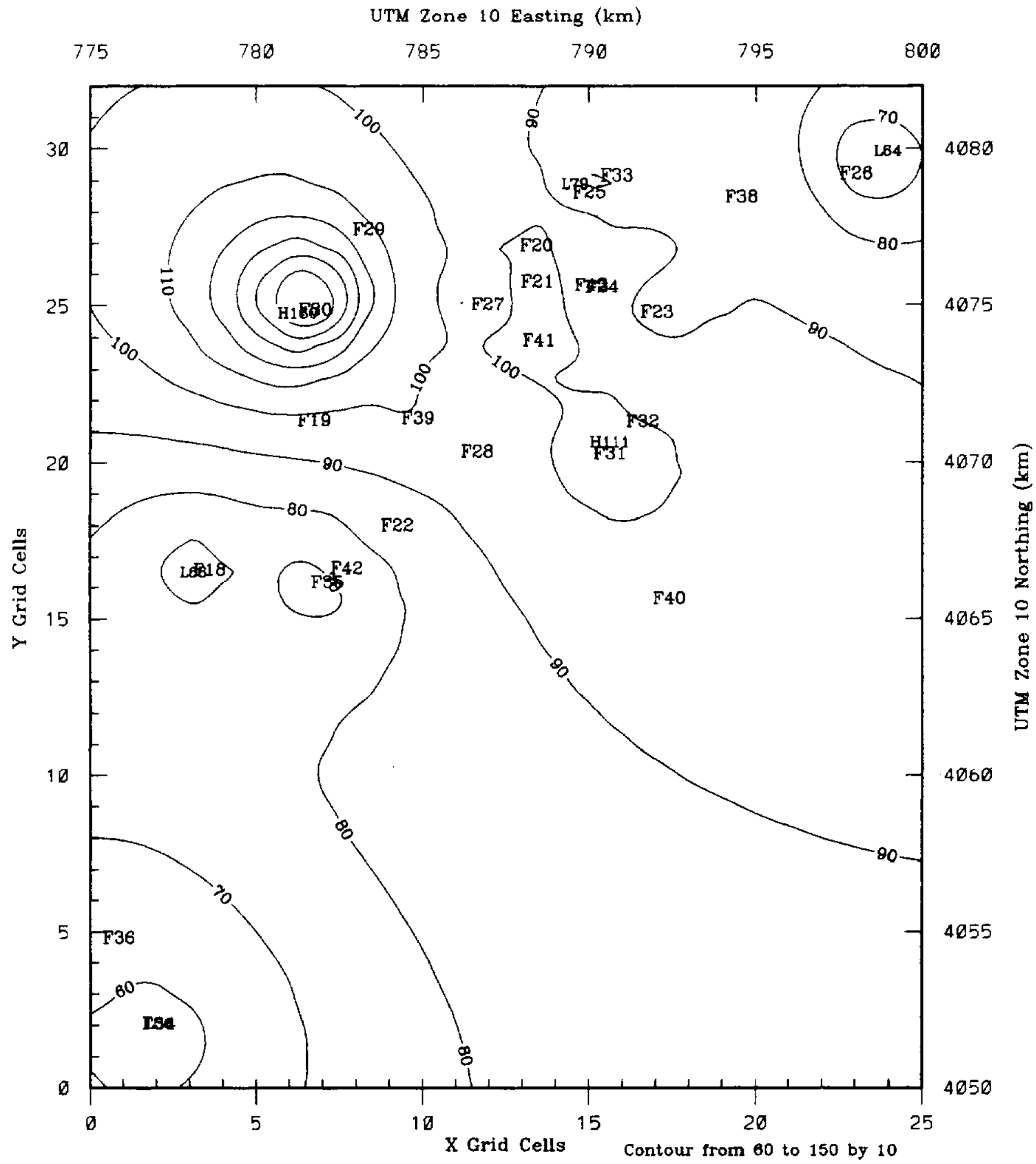


Figure 10. PM10 secondary species at Fresno saturation sites.



Fresno Saturation Sites
PM10 Mass (ug/m3)
on Day 960106

IMS95 Data Analysis

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Figure 11. Contour plot of PM10 mass on January 6, 1996, at Fresno saturation sites.

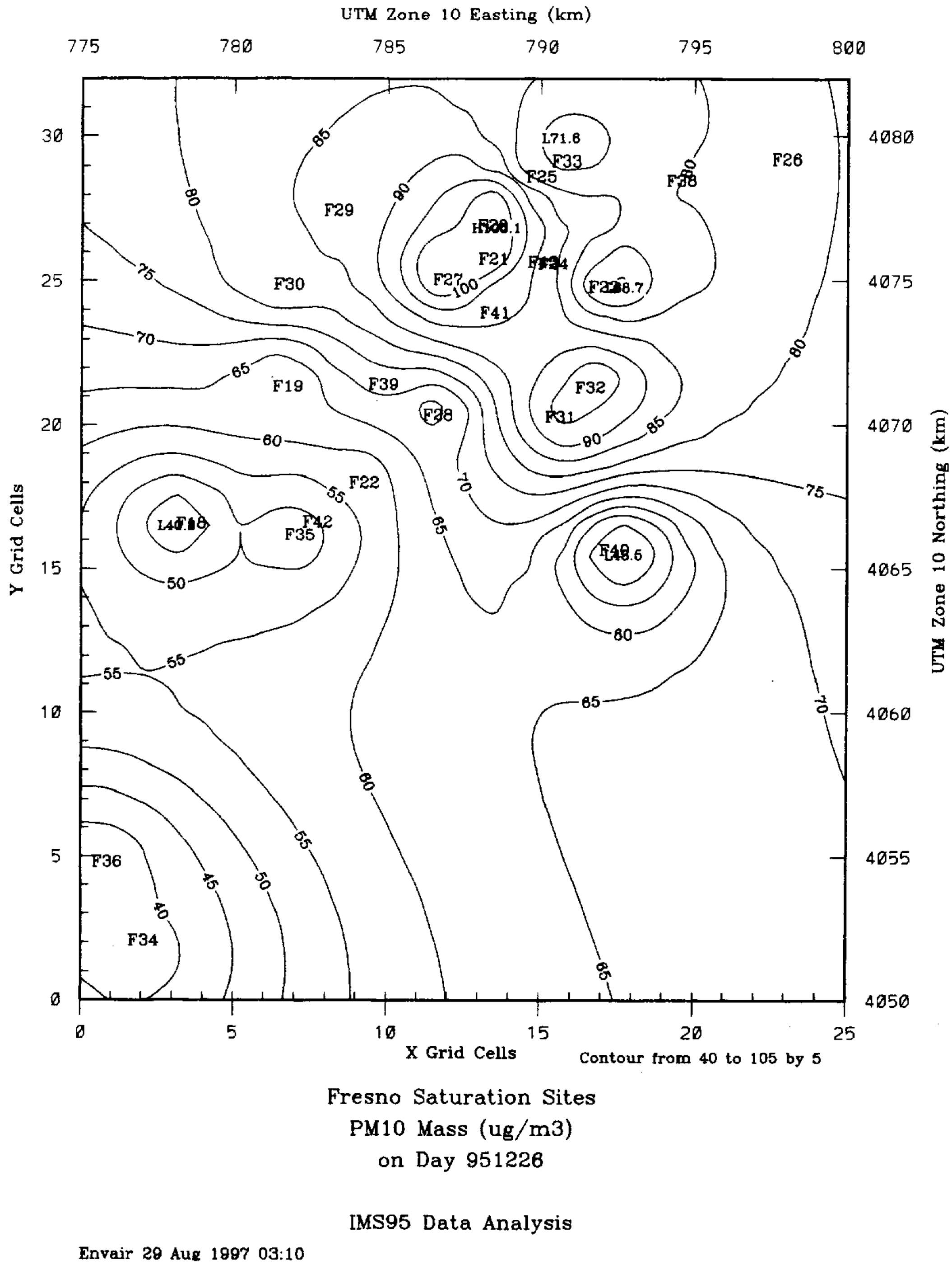
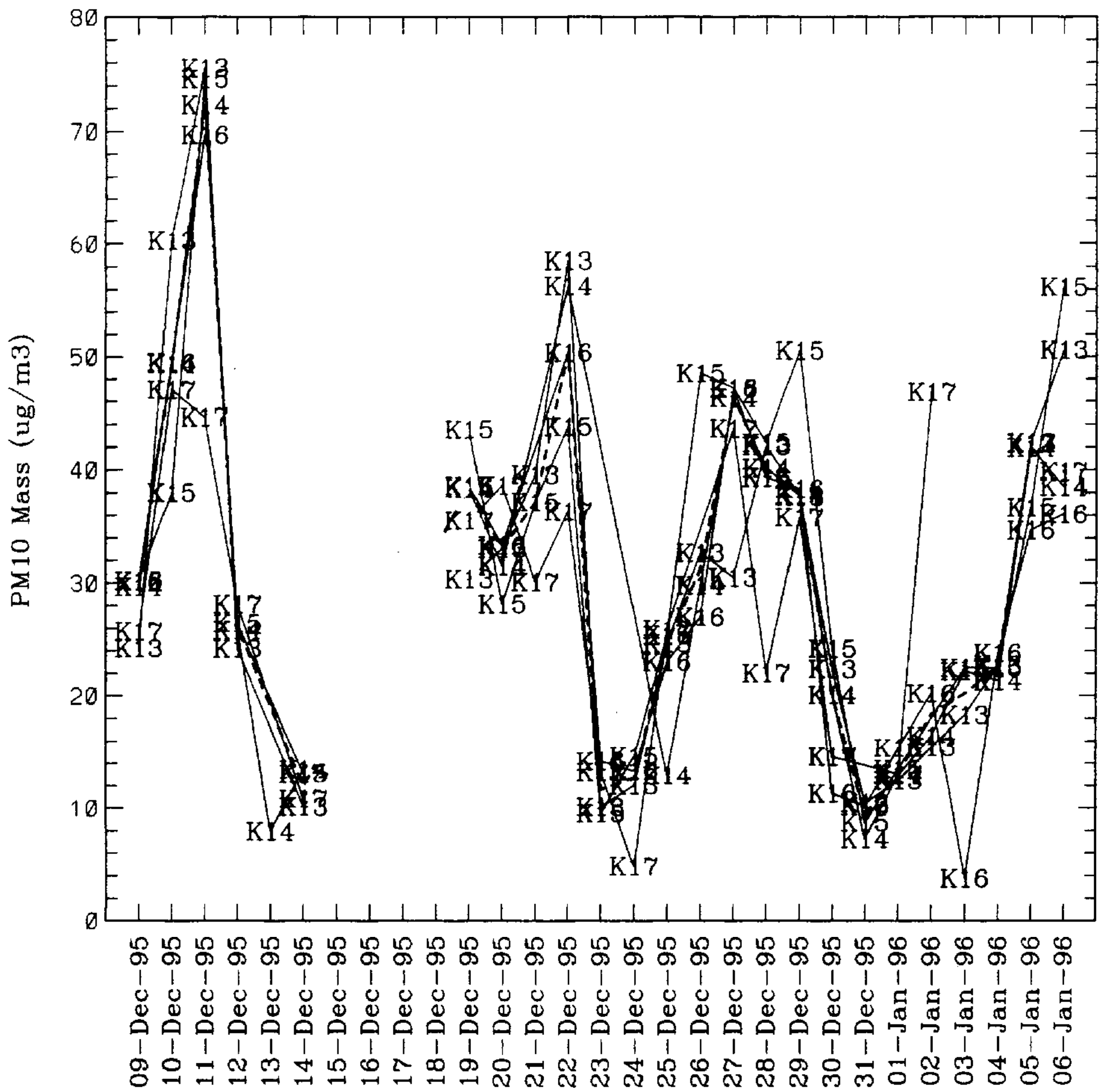


Figure 12. Contour plot of PM10 mass on December 26, 1995, at Fresno saturation sites.

All Kern Wildlife Refuge Saturation Sites
(Sites 13 - 17)
PM10 Mass (ug/m3)
From 9 December 1995 to 6 January 1996
IMS95 Data Analysis



The dashed line is the median of all Kern saturation sites.

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Figure 13. PM10 mass at Kern saturation sites.

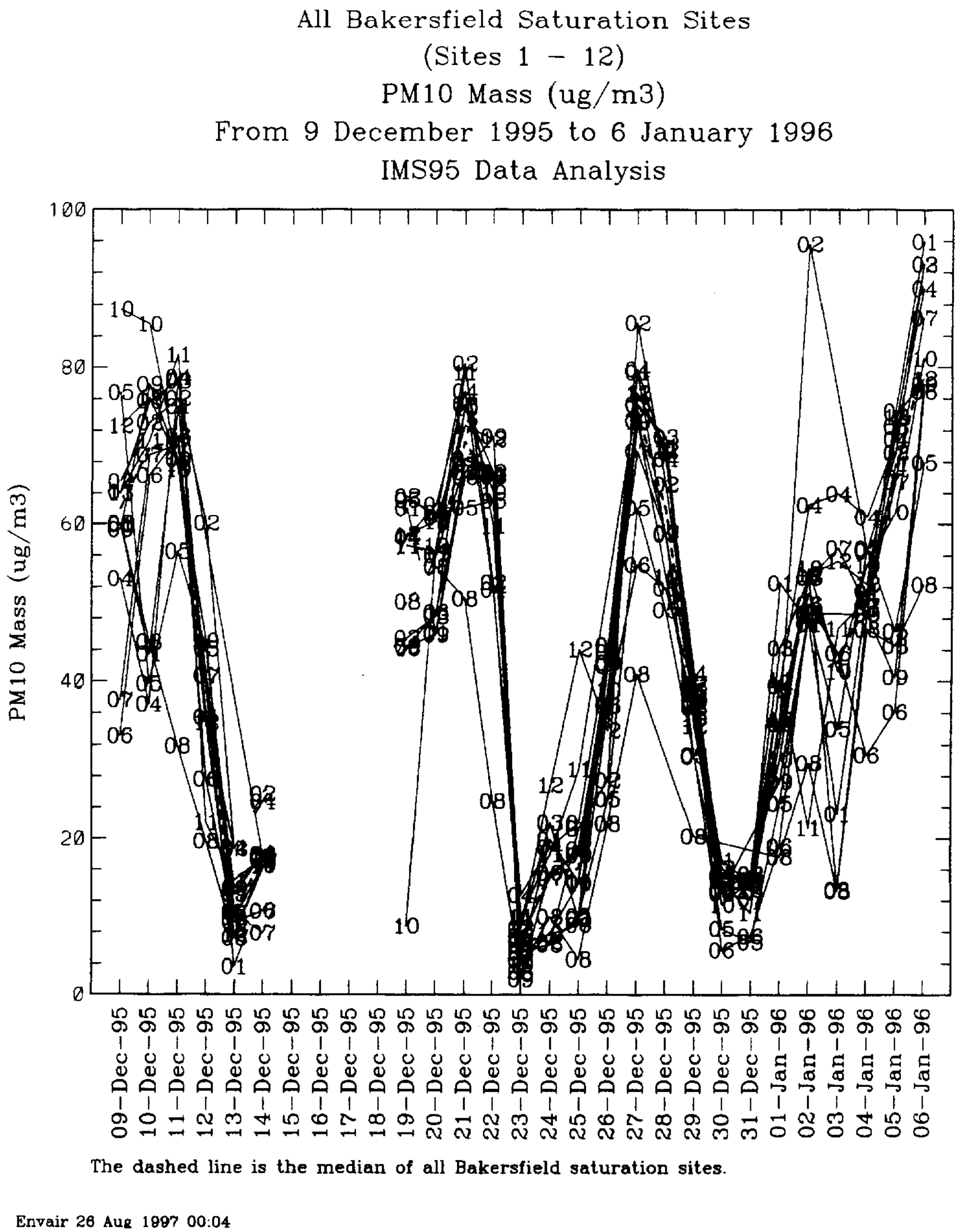


Figure 14. PM10 mass at Bakersfield saturation sites.

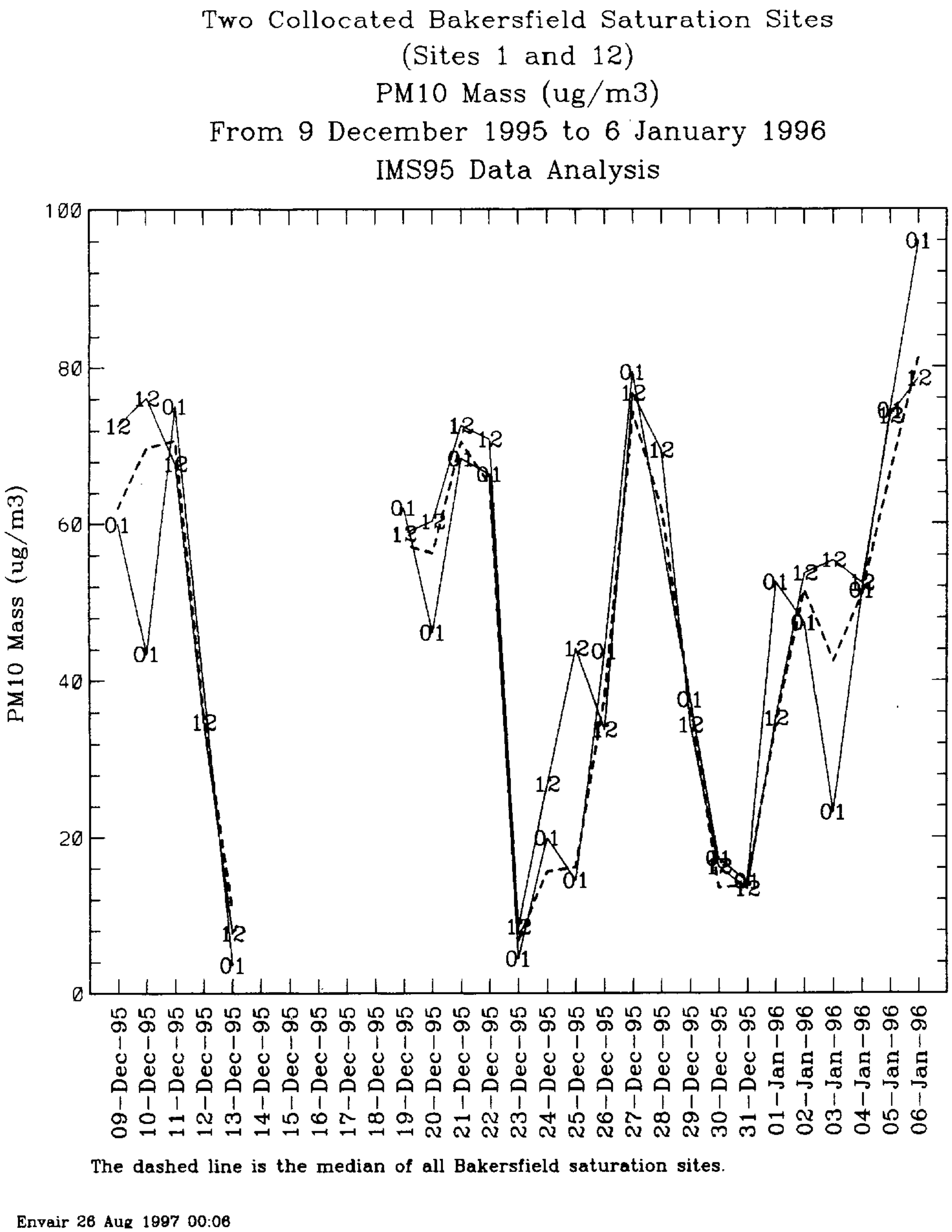


Figure 15. PM10 mass at two collocated Bakersfield saturation sites.

Collocated Measurements

The uncertainties listed in the database are analytical uncertainties and do not take into account sampling error. The analytical uncertainties show a smooth linear increase with concentration, with some superimposed scatter and a non-zero y intercept. When expressed as a percentage of concentration, the uncertainties asymptote to a constant at high concentration, but rise precipitously at low concentration as scatter and the y intercept become increasingly important. Mean analytical uncertainties are shown in Table 4 below. The very lowest values have been excluded to eliminate large percentages. (The number removed is shown by the difference between "N total" and "n used".)

The comparison of measurements from collocated samplers captures sampling error as well as analytical error. Unfortunately, sites B01 and B12 are the only two saturation sites that are collocated. They are about twelve meters apart. On a display of the saturation domain, F24 and F43 appear to be nearly collocated, but they are actually about 340 m apart, based on their coordinates, and so are inappropriate for analysis as collocated sites. C20 and C22 are described in *Operations and Measurements* (draft 6/14/97) as collocated, but their coordinates indicate that they are 1.9 km apart.

In contrast to the analytical uncertainties listed in the database, for PMT (n=22), the absolute difference between B01 and B12 shows no trend with concentration. For CRU (n=5), SEC (n=3), and CAR (n=4), the number of samples is too small and the noise too large to discern a tendency with concentration. If sample standard deviations are assumed to be constant with concentration, they can be calculated from the differences between measurements at collocated samplers. These standard deviations are shown in the Table 5 along with the mean concentrations.

Table 4. Mean analytical uncertainties. The lowest concentrations were excluded to avoid extremely high percent uncertainties. "N total" is the total number of samples; "n used" is the number actually employed in the calculation.

Species	N total	n used	Mean Conc. (μg/m^3)	Mean Uncertainty (μg/m^3)	Mean % Uncertainty (%)
PMT	1563	1539	55.5	3.41	7.70
CRU	345	325	15.2	2.90	18.9
SEC	212	209	22.0	1.14	4.81
CAR	225	225	18.0	2.09	14.7

Table 5. Standard deviations calculated from the differences between B01 and B12.

Species	n	Mean Conc. (μg/m^3	Sample Standard Deviation (μg/m^3)	Sample Standard Deviation (%)
PMT	22	47.5	9.87	27.9
CRU	5	5.31	0.64	14.6
SEC	3	23.2	3.22	12.9
CAR	4	21.8	5.62	22.9

Except for CRU, the uncertainties calculated from the differences between B01 and B12 are considerably higher than the analytical uncertainties. For CRU, the explanation of this difference is probably that the concentrations measured at B01 and B12 are much less than the IMS95 mean, reflecting the influence of the high CRU measurements at the Corcoran saturation sites. Conservatively, we should take the larger measure of uncertainty and so use the analytical uncertainty for CRU and the difference-calculated standard deviations for the others.

The existence of only one set of collocated samplers in only one saturation region means that our estimates of measurement uncertainty are poor. Is B01-B12 an uncharacteristically bad pair? Is it uncharacteristically good? Can its results be applied to regions other than Bakersfield? The small sample sizes for CRU, SEC, and CAR do not encourage confidence in the calculated sample standard deviations for these species and the analytical uncertainties represent a lower bound on the total sampling uncertainty.

Comparison of Saturation and Core Sites

Portable saturation samplers were collocated with the core-site sequential-filter samplers at Bakersfield, Fresno, Kern, and Corcoran. The 3-hour measurements from the sequential-fliter samplers were aggregated to match the 24-hour sampling intervals of the saturation monitors and the data were compared. The agreement was very good (see Appendix A). No offsets were evident and few substantial deviations between the saturation and core samplers occurred. The Fresno saturation sampler showed six values of PM_{10} mass that were about 20 $\mu g\ m^{-3}$ less than those recorded by the sequential filter sampler. Of the collocated saturation sites B01 and B12, B12 compared better with the sequential filter sampler than did B01.

SECTION 3: EVALUATION OF SITE CHARACTERISTICS

OBJECTIVES

The objective of this section is to verify the classifications of the IMS95 fall and winter monitoring sites. Sites are classified according to type (i.e., saturation, core, boundary/flux) and characteristic. We use the term "characteristic" to describe the site purposes listed in Table 4 of Solomon et al (1997a) and in Solomon et al (1997b). Site characteristics are listed in Table 6 below.

APPROACH

We evaluated site characteristics by comparing each designated site characteristic with information derived from gridded land use, population, and emissions files. In addition, we used the 1995 Integrated Monitoring Study CD-ROMs, which contain detailed site maps and photographs, and the site videos.

Site characteristics were originally designated based upon visual assessment of source types in the vicinity of each site, not on an assessment of source strength (Solomon et a., 1987a; 1987b). Thus, the comparison of the designated site characteristics with photos and videos was expected to largely corroborate the site characteristics. In contrast, the comparison of site characteristics with emissions provides an opportunity to cross-check the visual assessment of source types with estimated source strengths. The comparisons with population and land-use files were intended to provide a secondary set of cross-checks. As discussed below, several instances were identified in which the population and land-use estimates were at variance with photos and videos.

Recommended changes in the designated site characteristics are made for ten sites. An additional 16 sites are identified whose designated characteristics are consistent with their immediate surroundings (based on photos and videos), but where emissions are not dominated by sources of the designated classification.

Table 6. Characteristics of core, saturation and boundary/flux sites.[1]

Category	Subcategory	Abbreviation
Agricultural		
	General / Mixed crop and animal farms, native vegetation	AgGen
	Cotton/alfalfa/corn, citrus, nuts, vineyards, other crops	AgCrop
	Dairy	AgDairy
	Poultry	AgPoultry
	Native Vegetation	AgNative
Industrial		
	General	IndGen
	Oil processing and refining	IndOil
	Agricultural related (grain silos, cotton ginning, storage areas)	IndAgr
	Wastewater treatment plants	IndWaste
	Construction	IndConst
Rural/Regional	General	RurGen
Residential		
	General	ResGen
	Wood smoke	ResWood
Transportation		
	Residential neighborhood	TransRes
	Mixed commercial/residential traffic	TransMix
	Railroad/commercial traffic/agricultural	TransRR
Urban		
	Commercial (restaurants, shopping, offices)	UrbCom
	General/Mixed residential and commercial (shopping, offices)	UrbGen
Boundary		
	Rural clean air	BndClean
	East or West side but within valley	BndSide
Transport		
	Through pass into or out of valley	ThruVal
	Northern flux plane	ThruNor
	Central flux plane	ThruCen

[1] Transport and boundary characteristics apply only to boundary/flux sites. Some sites are also described as collocated or interstitial.

DATA REQUIREMENTS

Gridded land use, population, and emissions files were obtained and converted to a format useful for verifying site designations. The area emissions files as received were day- and hour-specific and covered 113 source categories. Information on source categories (definitions and emission rates) was used to aggregate area emissions into useful groups. We reaggregated the area emission estimates as daily averages for the following categories:

- farming operations
- entrained road dust (paved)
- entrained road dust (unpaved)
- construction and demolition
- fugitive windblown dust
- residential fuel combustion
- agricultural waste burning
- non-road mobile
- industrial fuel production
- industrial processes (non-point)

Together with the mobile- and point-source emissions estimates, these categories of area emissions allowed us to determine if a monitoring site was located in a grid-cell where primary PM emissions were dominated by agricultural, residential, industrial, or transportation sources. We used emissions estimates from two days, November 13, 1995 and January 5, 1996 in our analyses.

METHODS

For each site, we first examined land use categories, population, and emissions in the grid cell in which the monitoring site was located. We then examined the set of 25 cells (a 20 km x 20 km area) surrounding each site. These choices of area were based upon the grid size and our estimation of the likely area of influence of emission sources (in Section 6 of this report, it is shown that emission sources within a few kilometers of a site influence the site most heavily and sources within approximately 20 km exert varying and non-negligible influences). In the case of the population files, though, the 5-cell-by-5-cell areas were scaled back to 3 cells by 3 cells, because populations varied widely from cell to cell and we felt that using the smaller (3 cell by 3 cell) scale would provide a better indication of the population close to each site.

To compare population with site designations, we averaged the population in the 9 cells encompassing the monitoring site location and compared both this average and the one-cell population values to a set of population density criteria. As criteria, we estimated that a reasonable population for agricultural and rural areas would be less than 2,000 people per cell, and that residential and urban areas should have a population greater than 20,000 people per cell. These criteria are equivalent to 1.25 people ha^{-1} (3.1 people $acre^{-1}$) and 12.5 people ha^{-1} (31 people $acre^{-1}$), respectively. (At about 3 people per house, the criteria are thus <1 and >10 houses $acre^{-1}$).

To compare emissions with site designations, we first generated four emission profiles for each site (examples are shown later). Each profile describes the percentage contribution to total emissions due to agricultural, industrial, mobile, and residential sources. For each site, the four profiles included emissions estimated from two days (November 13 and January 5) and two spatial scales (the one grid cell containing a site and the 5x5 grid centered on a site). We also generated emission profiles averaged across groups of sites, where the grouping was done according to the sites' primary designated purpose.

Where site designations did not conform to the gridded information, we examined the CD-ROM collection to determine if conflicts were due to erroneous site designations or to errors in the gridded files. We then identified site designations conflicting with CD-ROM information.

RESULTS

We first discuss the comparison of the sites' designated purposes with the information obtained from the emissions inventory. While many subclassifications exist, the sites' primary characteristics may be grouped into six categories: agricultural, industrial, residential, transportation, rural, and urban. For this evaluation, emissions were grouped into four categories: agricultural, residential, transportation (including mobile sources, other transportation sources such as railroads, paved and unpaved road dust, etc.), and industrial (including point sources and area emissions assigned to industrial sources). The comparisons yielded the results listed in Table 7 and shown graphically in Figure 16. Emissions compositions vary slightly between spatial scales, and even less so between days, so findings should not be too sensitive to the choice of inventory date or the spatial scale used. The following site purposes have very similar emissions compositions: agricultural/rural, residential/industrial, and transportation/urban. This similarity may imply that six different PM concentration profiles cannot be observed at the six types different types of monitoring stations. However, it may also reflect limitations in the assumptions about land use and emissions factors used to generate emissions estimates. Table 7 and Figure 16 also reveal several apparent inconsistencies:

- Transportation emissions comprise a greater proportion of emissions for urban sites than for transportation sites.
- Agricultural emissions are a greater proportion of emissions in rural sites than agricultural sites.
- Industrial emissions represent a smaller proportion of emissions in industrial sites than transportation, urban and residential sites.
- Industrial and residential emissions are very low regardless of the site purpose, representing less than 20 and 10 percent of emissions, respectively, in most cases, including sites designated as industrial and residential.

Table 7. Average emission profiles by site purpose, date, and spatial scale.

Primary Site Purpose	Number of Sites	Average Emissions Composition (%Industrial / %Transportation / %Agricultural / %Residential)			
		Site Cell on Nov 13, 1995	Site Cell on Jan 5, 1996	400 km^2 Area Around Site on Nov 13, 1995	400 km^2 Area Around Site on Jan 5, 1996
Agricultural	23	11 / 34 / 42 / 07	16 / 39 / 21 / 21	09 / 23 / 59 / 03	09 / 30 / 52 / 09
Industrial	14	14 / 37 / 39 / 04	20 / 41 / 25 / 13	15 / 29 / 47 / 04	17 / 32 / 41 / 10
Residential	19	17 / 33 / 40 / 06	21 / 36 / 26 / 15	14 / 27 / 49 / 05	16 / 31 / 41 / 12
Rural	10	02 / 28 / 59 / 01	05 / 29 / 44 / 04	03 / 27 / 60 / 01	06 / 33 / 56 / 04
Transportation	5	28 / 44 / 17 / 09	26 / 41 / 13 / 19	16 / 34 / 40 / 07	16 / 34 / 34 / 17
Urban	7	21 / 57 / 08 / 12	18 / 49 / 06 / 24	19 / 40 / 29 / 09	18 / 39 / 22 / 20

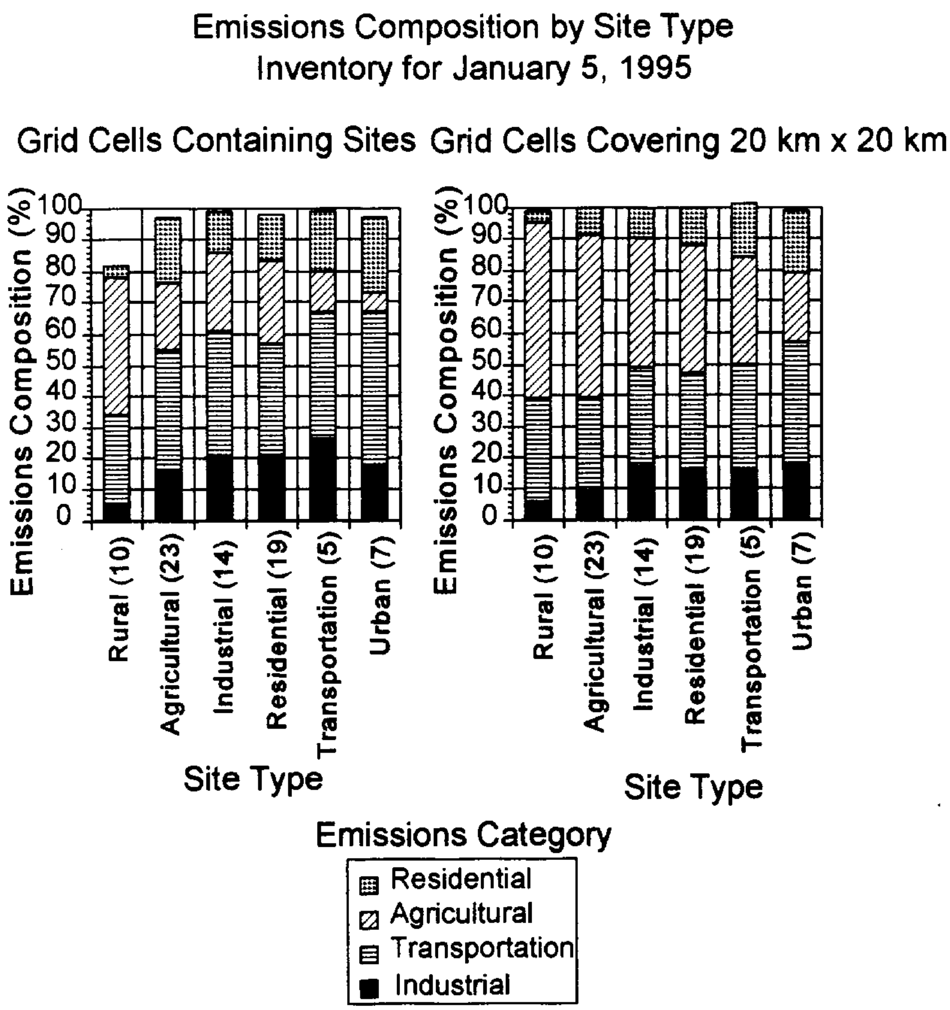


Figure 16. Average emissions composition (percent) for six types of sites based on the emission densities in the grid cell containing each site (left) and in the 25 grid cells centered on each site (right). The numbers of each type of site are in parentheses.

The points raised above are of concern because, for example, a putative industrial site may not exhibit any discernible influence from industrial sources because their contribution to PM concentrations at the site might be less than 20 percent. However, the local (< 1 km) environment of the site may indeed be industrial. Should such sites be designated industrial? A similar concern arises for the residential sites. We have maintained the original approach of designating sites according to their immediate surroundings. We flagged sites whose emission profiles were markedly different from others within the same site classification. To do so, a set of 24 figures was examined; Figures 17-22 are shown here as examples. It may be seen that:

- Eight of the 23 agricultural sites appear to have low (< 25 percent) agricultural emissions: 08B, 42F, 09B, 33F, 06B, LOO, CHO, and TEH. However, the latter three are boundary sites and are grouped with agricultural sites because their secondary characteristics were listed as agricultural.
- Eleven of the 14 industrial sites have less than 20 percent emissions from industrial sources. Only KRN, 05B, and 07B have more than a 30 percent industrial contribution.
- Most of the residential sites show less than 10 percent of emissions attributable to residential sources. Of the 19 sites, COA, 22F, 17C, and 41F show especially low residential emissions.
- Of the five transportation sites, all show 50 to 70 percent transportation emissions except 19F, which is dominated by industrial emissions.
- Rural sites are all dominated by agricultural emissions, as expected, except FRI, whose primary purpose is actually "boundary."
- The emissions profiles for the urban sites are generally similar to each other and show 15 to 20 percent industrial emissions, 40 to 60 percent transportation, and 15 to 20 percent residential.

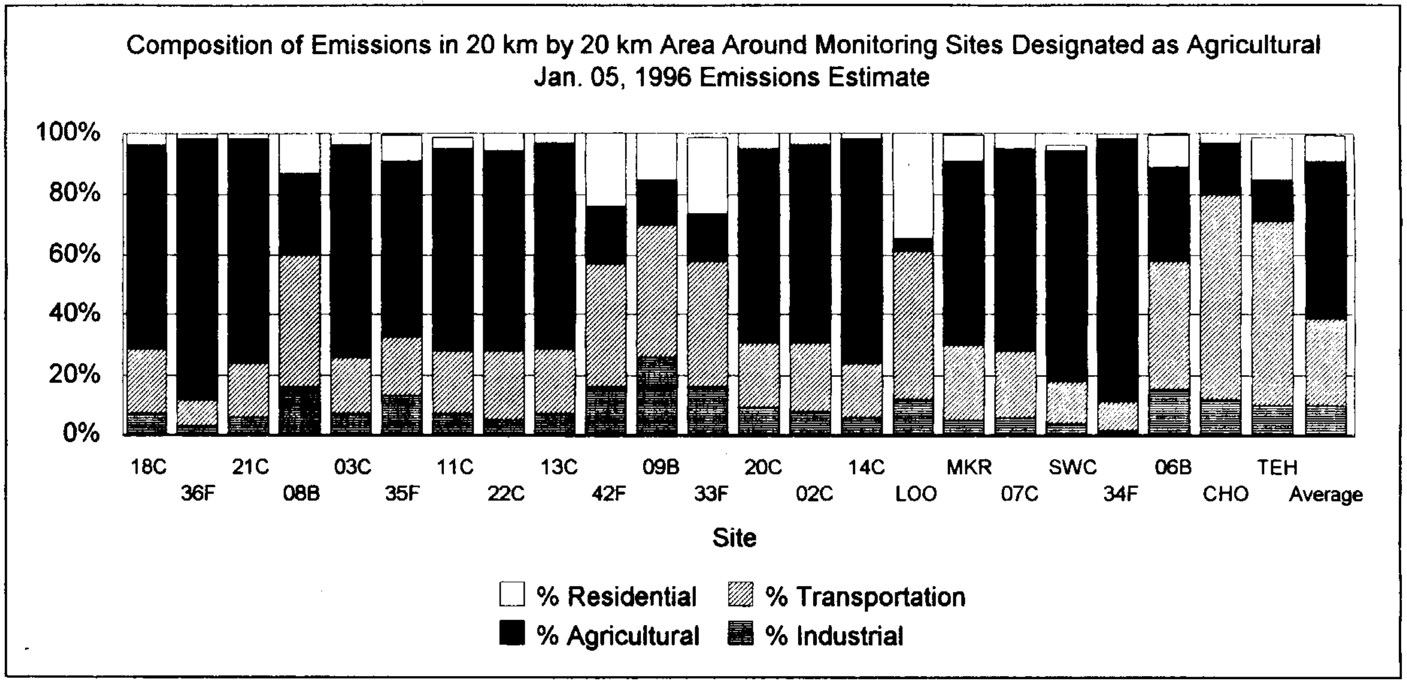


Figure 17. Composition of emissions on January 5, 1996, in 20 km by 20 km areas surrounding sites having a primary designation of agricultural. Sites LOO, CHO, and TEH are boundary sites whose secondary designations are agricultural.

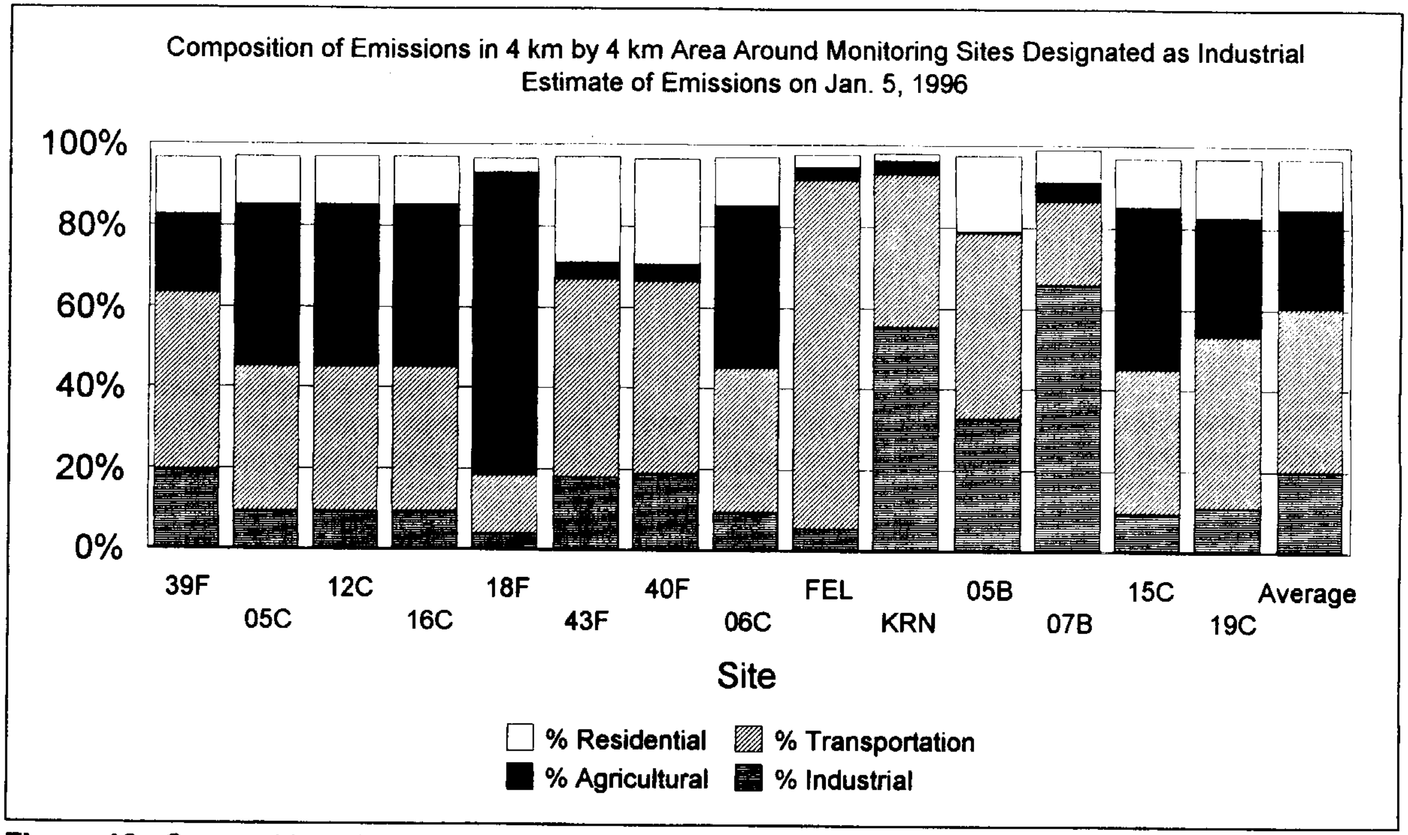


Figure 18. Composition of emissions on January 5, 1996, in 4 km by 4 km areas surrounding sites having a primary designation of industrial.

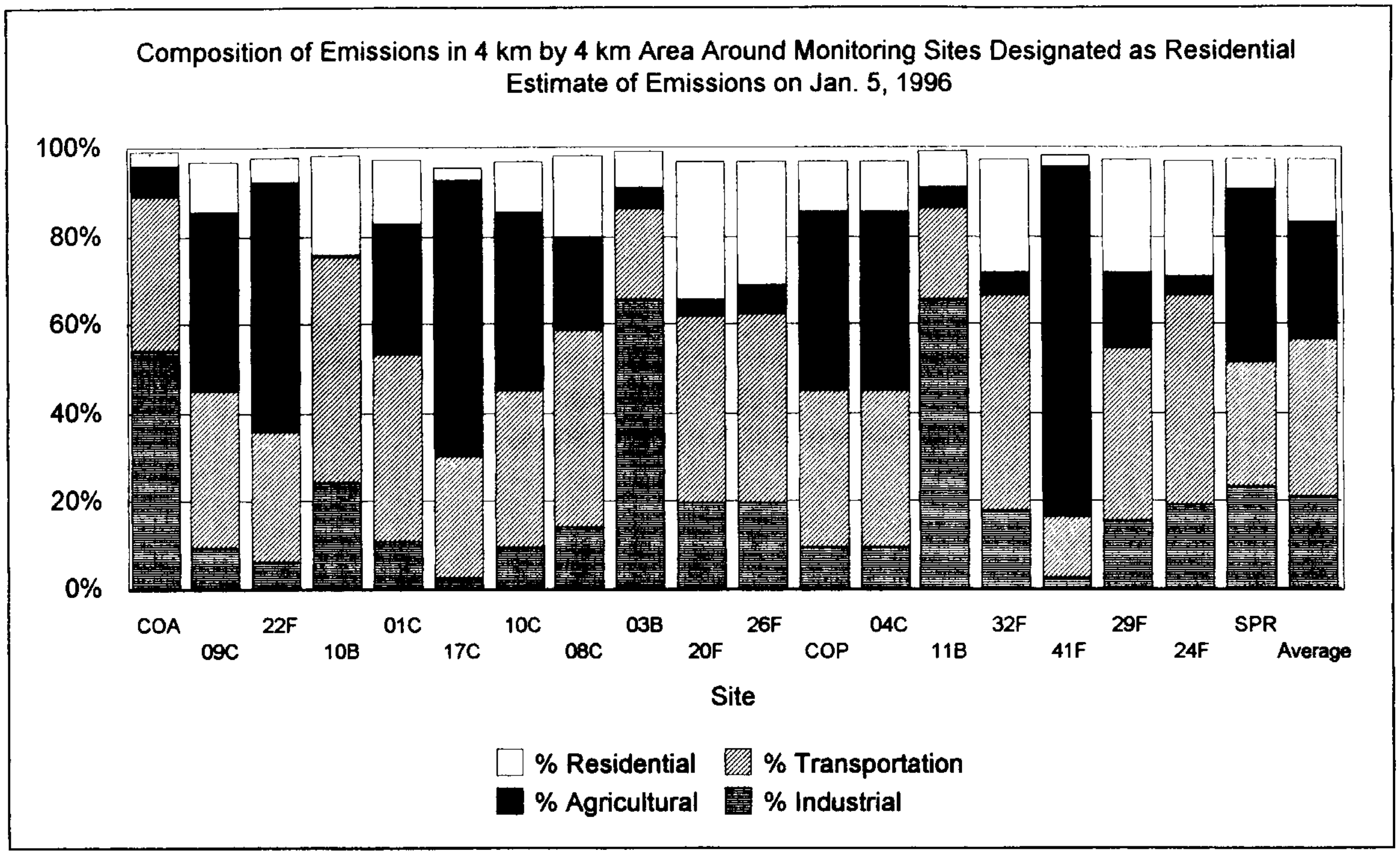


Figure 19. Composition of emissions on January 5, 1996, in 4 km by 4 km areas surrounding sites having a primary designation of residential.

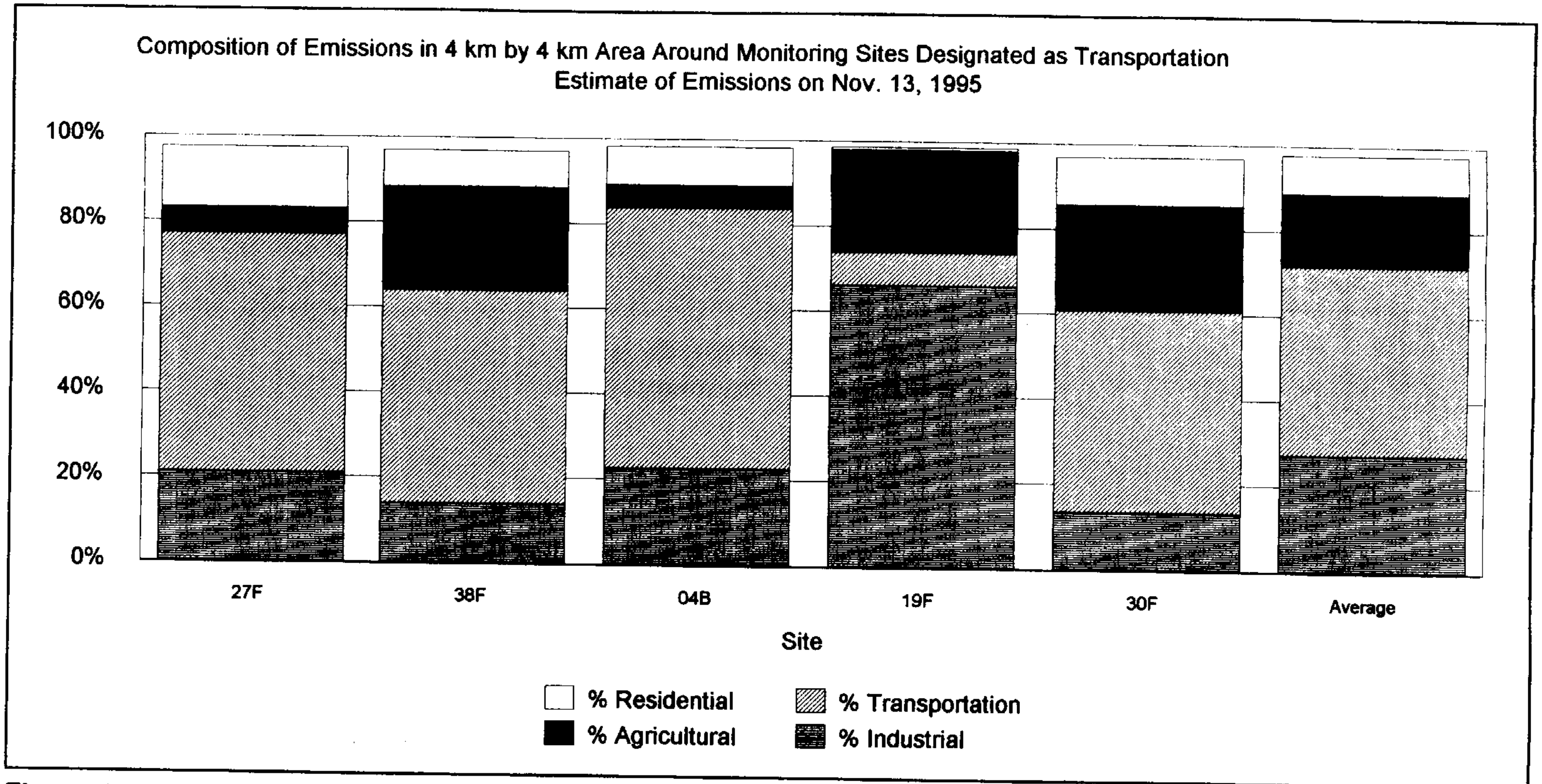


Figure 20. Composition of emissions on November 13, 1995, in 4 km by 4 km areas surrounding sites having a primary designation of transport.

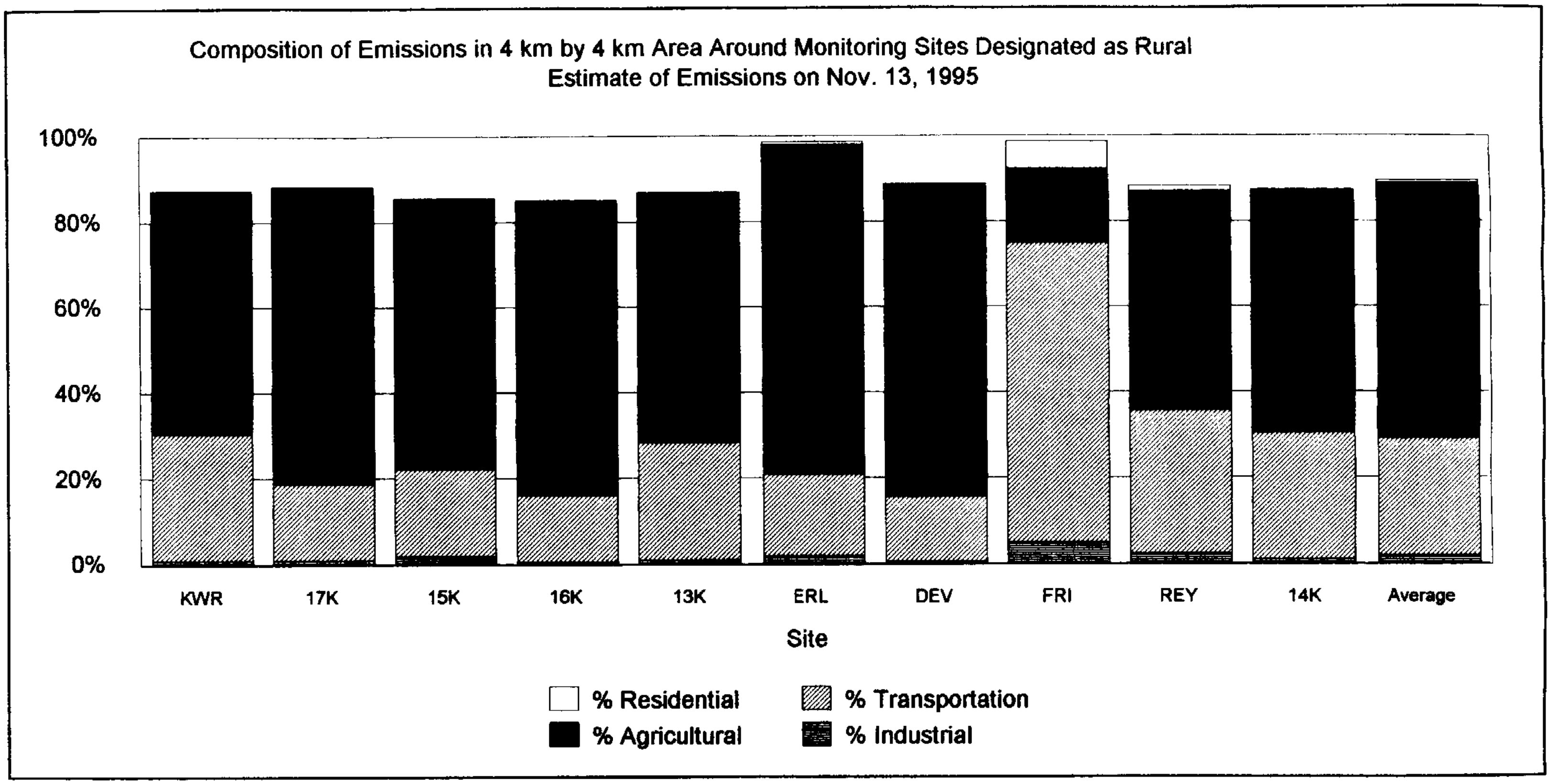


Figure 21. Composition of emissions on November 13, 1995, in 4 km by 4 km areas surrounding sites designated as rural.

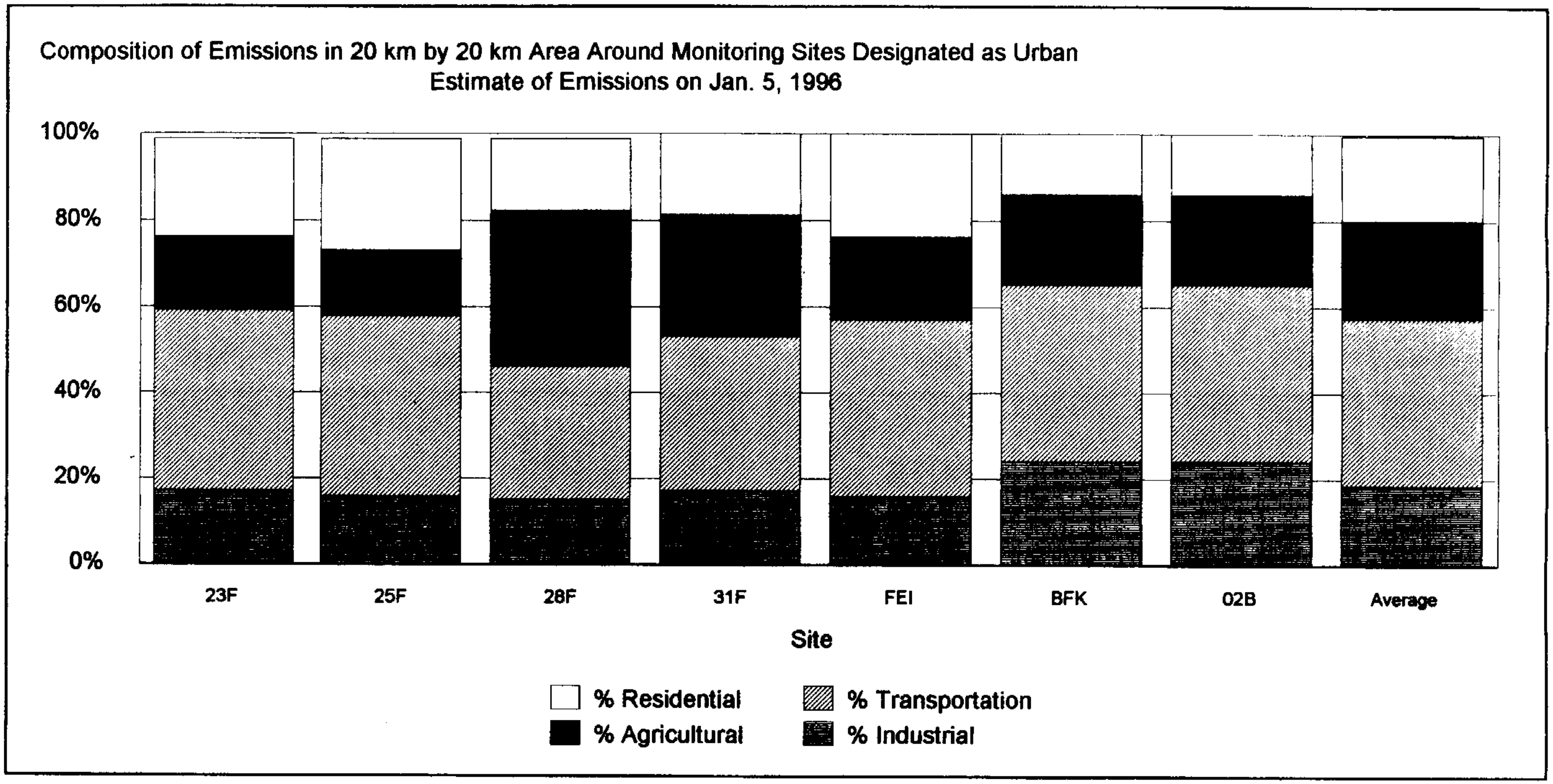


Figure 22. Composition of emissions on January 5, 1996, in 20 km by 20 km areas surrounding monitoring sites having a primary designation of urban.

In Table 8, we list monitoring sites with designations that conflict with information in the gridded land use, population, or emissions files at either the one-cell or multi-cell levels, or that conflict with information in the IMS95 CD-ROM collection. A more detailed description of the conflicts is shown in the table in Appendix B. Conflicts associated with the emission profiles were discussed above. In addition, as indicated in Appendix B, many sites that are designated as urban or residential are located in grid cells that are classified as agricultural in the land-use file. However, our review of information in the CD-ROM indicates that for most of these discrepancies the sites are indeed urban or residential, and, therefore, the land-use files appear to be inaccurate (the land-use files are 4 x 4 km resolution, whereas photos and videos depict areas within about one km of a monitoring site, so the difference in scale may be a factor in some cases). Similarly, comparisons of site designations to the population file reveal other discrepancies. As was the case for the land-use file, information on the CD-ROM generally supported the site designations, thus suggesting that the population file may be out of date or otherwise inaccurate for some areas.

Table 8. Summary of information that conflicts with designated site characteristics.

Site	Site Name	Site Type	Characteristic[1,2]	Source of Conflicting Information[3]
BFK	Bakersfield-Van Horn School	Core/Wntr	UrbGen, ResGen, UrbCom, TransMix, IndOil	LU
CHO	Cholame	Boundary	ThruVal, AgNative	E, CD
COA	Coalinga	Boundary	BndSide, ResGen, IndOil, AgNative	LU, P, CD
COP	Corcoran-Van Dorsten	Core/Fall	ResGen, UrbGen	LU, P
ERL	Earlimart	Bndry/Flux	BndSide, RurGen, AgGen, IndOil	CD
FEI	Fresno-Einstein Park	Core/Wntr	UrbGen, ResGen, ResWood, TransRes, TransMix	LU
FEL	Fellows	WSO/MET	IndOil, AgGen, AgCrop	E
FRI	Friant	Boundary	ThruNor, RurGen, AgNative	E
LOO	Lookout Point	Boundary	BndClean, AgNative	E
SPR	Springville	Bndry/Flux	ThruCen, ResWood, AgNative	LU, P
THE	Tehachapi	Boundary	ThruVal, AgNative	E, CD
01B	Bakersfld Sat. Site 01- CORE -Van Horn School	Wntr/Satur	Collocated	LU
02B	Bakersfld Sat. Site 02 - Chester	Wntr/Satur	UrbGen, ResGen, UrbCom, TransMix	LU
03B	Bakersfld Sat. Site 03 - El Rio	Wntr/Satur	ResGen, ResWood, TransRes	LU, CD
04B	Bakersfld Sat. Site 04 - Stockdale	Wntr/Satur	TransMix, UrbGen	LU
05B	Bakersfld Sat. Site 05 - China Grade	Wntr/Satur	IndOil, IndGen	LU
06B	Bakersfld Sat. Site 06 - Santa Fe	Wntr/Satur	AgCrop, AgGen, AgNative, Interstitial	E
07B	Bakersfld Sat. Site 07 - Truxtun	Wntr/Satur	IndOil, UrbGen, IndGen, UrbCom	LU
08B	Bakersfld Sat. Site 11 - Fairway	Wntr/Satur	AgCrop, AgGen, TransRR	E
09B	Bakersfld Sat. Site 09 - Mohawk	Wntr/Satur	AgGen, AgGen, AgCrop, AgNative	E
10B	Bakersfld Sat. Site 10 - Warren	Wntr/Satur	Collocated, ResGen, TransRes, IndOil	LU

Site	Site Name	Site Type	Characteristic[1,2]	Source of Conflicting Information[3]
11B	Bakersfld Sat. Site 11 - Fairway	Wntr/Satur	ResWood, ResGen	LU
12B	Bakersfld Sat. Site 12-CORE Van Horn School	Wntr/Satur	Collocated	LU
01C	Corc/Han Sat. Site 01- Irwin	Fall/Satur	ResGen	LU
02C	Corc/Han Sat. Site 02 - Nevada	Fall/Satur	AgNative, RurGen	CD
04C	Corc/Han Sat. Site 04 - Van Dorsten	Fall/Satur	ResGen, UrbGen, Collocated	LU
05C	Corc/Han Sat. Site 05 - Pickrell	Fall/Satur	IndAgr, IndGen, TransRR	CD, E
06C	Corc/Han Sat. Site 06 - Yoder	Fall/Satur	IndGen, TransRR	LU, CD, E
07C	Corc/Han Sat. Site 07 - Newark	Fall/Satur	Interstitial, AgCrop	CD
08C	Corc/Han Sat. Site 08 - Josephine	Fall/Satur	ResGen, IndAgr	LU, P
09C	Corc/Han Sat. Site 09 - Canal	Fall/Satur	Interstitial, ResGen, AgCrop	LU, P
10C	Corc/Han Sat. Site 10 - Jensen	Fall/Satur	ResGen, Interstitial	LU
11C	Corc/Han Sat. Site 11 - Paris	Fall/Satur	AgDairy	CD
12C	Corc/Han Sat. Site 12 - King	Fall/Satur	IndAgr, ResGen, TransRR	E
15C	Corc/Han Sat. Site 15 - Pueblo	Fall/Satur	IndWaste, IndAgr	CD, E
16C	Corc/Han Sat. Site 16 - Bainum	Fall/Satur	IndAgr, ResGen, TransRR, Interstitial	E, P
17C	Corc/Han Sat. Site 17 - Miller	Fall/Satur	ResGen, AgGen, Interstitial	LU, P
19C	Corc/Han Sat. Site 19 - Wastewater	Fall/Satur	IndWaste, TransRR, AgCrop	P
18F	Fresno Sat. Site 18 - Cornelia	Wntr/Satur	IndConst, AgGen, AgCrop	CD, E
19F	Fresno Sat. Site 19 - Nielson	Wntr/Satur	TransRes, ResGen	CD, E
20F	Fresno Sat. Site 20 - Swift	Wntr/Satur	ResGen, ResWood, TransRes	LU
22F	Fresno Sat. Site 22 - Hyde	Wntr/Satur	Interstitial, ResGen, AgCrop	LU, CD
23F	Fresno Sat. Site 23 - Fresno Air Terminal	Wntr/Satur	UrbCom, IndGen, TransMix	LU, CD
24F	Fresno Sat. Site 24 - Meridien	Wntr/Satur	ResWood, ResGen, TransRes, IndConst	LU

Site	Site Name	Site Type	Characteristic[1,2]	Source of Conflicting Information[3]
25F	Fresno Sat. Site 25 - Library	Wntr/Satur	UrbCom, ResGen, TransMix	LU
26F	Fresno Sat. Site 26 - Coventry	Wntr/Satur	ResGen, TransRes	LU, CD
28F	Fresno Sat. Site 28 - Fresno	Wntr/Satur	UrbCom, TransMix	E
29F	Fresno Sat. Site 29 - Browning	Wntr/Satur	ResWood, ResGen, TransRes	LU
31F	Fresno Sat. Site 31 - Kings Canyon	Wntr/Satur	UrbCom, UrbGen, TransMix	LU
32F	Fresno Sat. Site 32 - Illinois	Wntr/Satur	ResWood, ResGen, TransRes	LU
33F	Fresno Sat. Site 33 - Barstow	Wntr/Satur	AgGen, ResGen, UrbCom, TransRes, AgDairy	P, E
35F	Fresno Sat. Site 35 - Jensen	Wntr/Satur	AgDairy	P
39F	Fresno Sat. Site 39 - Palm	Wntr/Satur	IndAgr, IndGen	CD, P
40F	Fresno Sat. Site 40 - Malags	Wntr/Satur	IndGen, AgCrop	P
41F	Fresno Sat. Site 41 - Weldom	Wntr/Satur	ResWood, ResGen, TransRes	LU, P
42F	Fresno Sat. Site 42 - Jensen	Wntr/Satur	AgDairy, AgGen	P, E
43F	Fresno Sat. Site 43 - Barton	Wntr/Satur	IndConst, AgGen, TransRes	CD, P

1 Refer to Table 6 for definitions of site characteristic abbreviations.
2 The first characteristic is the site's primary source
3 LU = Land Use, P = Population, CD = CD-ROM, E = Emissions

CONCLUSION

The principal conclusions are:

- Three sites are located west of the western boundary of the IMS95 monitoring domain: LBS (North Los Banos) and the meteorological sites PAN (Sonic 1 - Panoche Water District) and WCT (Candelabra Tower in Walnut Grove). We recomputed UTM coordinates from the latitudes and longitudes. Our recomputed UTM coordinates agreed with those given in the site list file to within

0.1 km in each direction (east and north) for all 95 sites.

- We compared the site designation of eighty one (81) sites against the gridded land use, population and emissions data and with the CD-ROM information. Fifty seven (57) of the sites had a conflict, as listed in Table 8.

- Eighteen (18) sites have primary characteristics that conflict with their emissions information. They either conflict with the average emissions profile for sites with the same primary site classification or have a very small contribution from the relevant source type. In addition, most sites designated residential and industrial have small contributions from residential and industrial sources..

- Thirty one (31) sites have designated characteristics that conflict with the gridded land use files. In most cases, the land use is defined as agricultural, but the characteristic is residential or urban. Analysis of the CD-ROM collection suggests that in most cases, the land use files are inaccurate. Therefore, we recommend that the gridded land use data be reviewed for accuracy.

- Fourteen (14) sites have designations that conflict with the gridded population files. For seven (7) of these 14, the population appeared too small for a residential site. The population appeared too large for the remaining seven (7) sites, which were classified as either agricultural or industrial. After referencing the CD-ROM information, we conclude that, in most cases, the gridded population file is probably erroneous and warrants investigation.

- Nineteen (19) sites have CD-ROM information that conflicts with site characteristics. In most cases, the site designation does not include a potential emissions source noted in the CD-ROM information (see appendix).

We make the following recommendations:

- Review the land use file for accuracy. Our analysis suggests that, in many instances, conflicts arise from errors in the land use files rather than erroneous site designations.

- Where population information conflicts with site classifications, we recommend reviewing the population file for accuracy when the CD-ROM information confirms a site designation. Otherwise, change the site designation to one consistent with the land uses shown on the CD-ROM and then recheck the population file.

Based on the foregoing, we propose modifying the site designations as shown in Table 9. For only one site (19F) is there a recommended change to the primary characteristic. Emissions in the grid cell containing site 19F are dominated by industrial sources and site photos show industrial facilities. For lack of more specific information, we suggest reclassification as "Industrial-general" (Ind Gen).

In Table 10, we list sites requiring additional examination to determine if site designation changes are desirable in light of information derived from the emissions files. As indicated above, the classifications of these sites are consistent with their immediate surroundings; however, emissions are not dominated by sources of the designated classification.

Table 9. Recommended changes to site classifications.

Site	Site Name	Characteristic[1,2] (Changes in **Bold** and ~~Strikeout~~)
CHO	Cholame	ThruVal, **TransRR**
COA	Coalinga	BndSide, ~~ResGen~~, IndOil, AgNative
ERL	Earlimart	BndSide, RurGen, AgGen, ~~IndOil~~
07C	Corc/Han Sat. Site 07 - Newark	Interstitial, AgCrop, **ResWood or ResGen**
11C	Corc/Han Sat. Site 11 - Paris	AgDairy, **ResWood or ResGen**
19F	Fresno Sat. Site 19 - Nielson	**IndGen**, TransRes, ResGen
22F	Fresno Sat. Site 22 - Hyde	Interstitial, ResGen, AgCrop, **IndConst, IndGen**
23F	Fresno Sat. Site 23 - Fresno Air Terminal	UrbCom, IndGen, TransMix, **ResWood or ResGen**
26F	Fresno Sat. Site 26 - Coventry	ResGen, TransRes, **AgCrop**
43F	Fresno Sat. Site 43 - Barton	IndConst, ~~AgGen,~~ TransRes

[1] Refer to Table 6 for definitions of site characteristic abbreviations
[2] The first characteristic is the site's primary purpose

Table 10. Sites classifications conflicting with emissions estimates but consistent with immediate surroundings.

Site	Site Name	Characteristic[1,2]
FEL	Fellows	IndOil, AgGen, AgCrop
FRI	Friant	ThruNor, RurGen, AgNative
LOO	Lookout Point	BndClean, AgNative
THE	Tehachapi	ThruVal, AgNative
06B	Bakersfld Sat. Site 06 - Santa Fe	AgCrop, AgGen, AgNative, Interstitial
08B	Bakersfld Sat. Site 11 - Fairway	AgCrop, AgGen, TranRR
09B	Bakersfld Sat. Site 09 - Mohawk	AgGen, AgGen, AgCrop, AgNative
05C	Corc/Han Sat. Site 05 - Pickrell	IndAgr, IndGen, TransRR
06C	Corc/Han Sat. Site 06 - Yoder	IndGen, TransRR
12C	Corc/Han Sat. Site 12 - King	IndAg, ResGen, TransRR
15C	Corc/Han Sat. Site 15 - Pueblo	IndWaste, IndAgr
16C	Corc/Han Sat. Site 16 - Bainum	IndAgr, ResGen, TransRR, Interstitial
18F	Fresno Sat. Site 18 - Cornelia	IndConst, AgGen, AgCrop
28F	Fresno Sat. Site 28 - Fresno	UrbCom, TransMix
33F	Fresno Sat. Site 33 - Barstow	AgGen, ResGen, UrbCom, TransRes, AgDairy
42F	Fresno Sat. Site 42 - Jensen	AgDairy, AgGen

[1] Refer to Table 6 for definitions of site characteristic abbreviations
[2] The first characteristic is the site's primary purpose

SECTION 4: PRINCIPAL COMPONENTS ANALYSIS

OBJECTIVES

The objective of this section is to use principal components analysis (PCA) to identify groups of sites with similar temporal patterns. The results were to be examined to determine if site groupings could be associated with geographical proximity, site type, or other factors, from which conclusions on the spatial scales of representativeness of sites might be drawn. As explained below, however, too few measurements were made over time at most sites to permit reliable application of the method. Therefore, the evaluation of spatial scales of representativeness was carried out through analysis of the spatial patterns of concentrations, as described in the next section. However, the PCA was useful for helping to identify data outliers and for providing supporting results for other analyses.

APPROACH

PCA extracts principal components, or factors, from a correlation matrix. The first component is associated with the largest eigenvalue of the correlation matrix, the second with the next largest, and so on. Usually, a limited number of components suffices to explain a large amount (e.g. 90 percent) of the total variance of a set of measurements.

One requirement of PCA is that the number of replicates exceed the number of variables. For the analyses here, replicates refers to dates and variables to sites. For PM measurements, fourteen dates were available in November (Nov. 1-14) for the Corcoran network. Twenty-nine dates were available in December and January (Dec. 9-13; Jan. 1-6) for the Bakersfield, Kern and Fresno networks. For the crustal (CRU), secondary (SEC) and carbon (CAR) species, nine dates were available in November (Nov. 6-14) and five dates were available in December and January (Dec. 26, 27; Jan. 4,5,6). In applying PCA, therefore, it was possible to analyze groups of thirteen and eight sites, respectively, for PM and species measurements in November. For

December and January, it was possible to analyze groups of twenty-eight and four sites for PM and species measurements, respectively. In cases where a saturation network had more sites than dates, two analyses were carried out, each for a subset of sites.

Sites in each of the Bakersfield, Corcoran, Fresno, and Kern regions were included when there was no missing data and no suspect data. In some cases, fewer sites were used than PCA would allow, due to the number of missing or suspect data points. Some analyses were repeated by including the sites with missing data, when possible.

RESULTS

Factor loadings for orthogonal rotations are shown in Figure 23 for each group of species and each network. For PM concentrations, the results show:

- In the Bakersfield area, PM concentrations at all sites are closely correlated with factor 1. The second factor largely consists of the contrast between B08 and B06. (The positive correlation of B08 with factor 2 was reduced but remained even after one unusual value, occurring December 18, was removed).

- All sites in the Corcoran area are correlated with factor 1, though one site, C18, is more related to a second factor. C18 shows one high value on November 2 (>180 $\mu g/m^3$), when the other sites ranged from 40 to 70 $\mu g/m^3$, and, as noted in Section 2, exhibits more variable concentrations than many of the other Corcoran sites. (According to the daily activity log, a large mound of gypsum was observed ~1 mile west of the C18 monitor on November 1, and was not noted on any other day. It is possible that the gypsum was shifted and applied to a nearby field on the morning of November 2. Occasional vehicles were seen driving on the dirt road near the monitor and farming activities were observed in the vicinity nearly every day, including November 2.)

PMT

	Factor 1	Factor 2
B01	**.931**	.003
B02	**.883**	-.011
B03	**.975**	-.105
B04	**.862**	.087
B05	**.880**	.333
B06	**.850**	-.438
B07	**.935**	-.250
B08	**.797**	.537
B09	**.928**	-.201
B10	**.945**	.128
B11	**.888**	-.036
B12	**.930**	.017

	Factor 1	Factor 2
C21	**.878**	-.166
C16	**.916**	.288
C17	**.951**	.198
C18	.596	**.766**
C19	**.941**	-.178
C12	**.893**	-.284
C10	**.978**	-.022
C08	**.964**	-.168
C07	**.940**	-.089
C04	**.977**	-.094
C01	**.972**	-.099
C02	**.908**	.126

	Factor 1	Factor 2
F21	**.883**	-.150
F23	**.915**	-.070
F31	**.881**	-.037
F34	.533	**.791**
F20	.734	-.391
F28	**.915**	-.002
F41	**.922**	.104

	Factor 1	Factor 2
K13	**.927**	-.138
K14	**.970**	-.098
K15	**.905**	-.221
K16	**.970**	-.026
K17	**.843**	.532

CARBON

	Factor 1	Factor 2
B07	**.972**	-.204
B09	**.923**	.236
B10	.083	**.995**
B12	**.951**	.234

	Factor 1	Factor 2
C20	.101	.782
C11	.516	**.808**
C13	.715	.686
C15	**.874**	.406
C19	**.940**	.085
C08	**.920**	.354
COY	**.910**	.323
C03	.673	.729
C05	.189	**.830**
C06	**.832**	.246

	Factor 1	Factor 2
F28	**.945**	-.299
F31	**.955**	-.016
F32	**.872**	.483
F35	**.971**	-.127

insufficient data

CRUSTAL

	Factor 1	Factor 2
B02	**.850**	.284
B04	**.968**	.206
B06	.215	**.959**
B08	.652	.610

	Factor 1	Factor 2
B05	**.945**	.143
B09	**.884**	-.376
B10	-.046	**.958**
B12	.723	.574

	Factor 1	Factor 2
C08	**.814**	-.462
C11	**.925**	.302
C13	**.795**	.598
C15	**.979**	-.052
C19	**.891**	-.298
C20	.656	.563
COY	**.843**	-.492
C03	**.922**	-.217
C05	**.872**	.186
C06	**.883**	.024

	Factor 1	Factor 2
F18	**.916**	.262
F22	**.870**	.443
F25	**.929**	.223
F31	**.981**	-.073
F35	.143	**.987**

	Factor 1	Factor 2
F32	**.957**	.228
F28	.744	.619
F23	.223	**.967**
F21	**.965**	.256

	Factor 1	Factor 2
K13	.619	.649
K14	**.997**	.040
K15	.033	**.969**
K16	**.944**	.200

SECONDARY

	Factor 1	Factor 2
B09	**.943**	.329
B10	**.964**	-.110
B12	**.957**	-.213

	Factor 1	Factor 2
COY	**.989**	.038
C08	**.996**	-.067
C11	**.984**	-.131
C13	**.989**	-.049
C15	**.987**	-.153
C20	**.920**	.388

	Factor 1	Factor 2
F28	**.978**	-.132
F35	**.943**	-.306
F32	**.879**	.475

insufficient data

Figure 23. Orthogonal factor scores of the Bakersfield, Corcoran, Fresno and Kern networks for PM10 (PM), carbon (CAR), crustal (CRU), and secondary (SEC) species.

- All sites in the Fresno area are highly correlated with factor 1, though the contrast between sites F34 and F20 constitutes a second factor. These two sites each showed several sharp concentration changes that were not correlated with each other (F34 was high Dec.14; F20 was low Dec. 20 and 27).

- In the Kern area, all sites PM series are explained by factor 1.

For each network, factor 1 explains 70-85 percent of the variance of PM mass. This large common correlation occurs because most of the variation of PM mass is associated with the rise and fall between episode and non-episode conditions. The first factor is likely associated with synoptic scale meteorology. While some individual sites exhibit secondary patterns as well, the secondary patterns are associated with a few individual sample points rather than with persistent differences among sites.

For carbon concentrations, Figure 22 shows:

- Three of the four Bakersfield sites are primarily explained by factor 1, with only one site, B10, significantly explained by factor 2. The differences relate to whether sites show concentration increases or decreases between Jan. 4th - 5th and Jan. 5th - 6th: the main difference between site B10 and the other three sites is that there is a smaller increase between Jan. 5th and 6th at B10.

- Five of the Corcoran sites (C06, C08, C15, C19 and COV) are correlated with factor 1, two sites (C11 and C13) are correlated with both factors 1 and 2, and two sites (C05 and C20) are primarily explained by factor 2. These groupings appear to relate to the uniquely high values at site C05 (see Figure 3 of Section 2) and, possibly, the proximity of sites C11 and C20 to the high emission densities occurring near site C05 (see late discussion and Appendix D). Also, sites in the first group have types "Residential" and "Industrial Waste" while sites in the second group are of types "Agricultural" or "Industrial - agriculture related."

- Fresno's four sites are predominantly explained by factor 1.

In all three regions, factor 1 explains 69-87 percent of the variance of carbon concentrations. Only in Corcoran is there some indication of a secondary temporal pattern affecting one or more of the sites.

For crustal elements, Figure 22 shows:

- With only 5 dates available for analysis, several different combinations of the 8 available Bakersfield sites were considered (not all are shown in Figure 22). The tabled results indicate high correlations between B02 and B04 and between B05 and B09. Time series plots show that sites B04, B05, B08 and B09 follow a similar pattern, as do sites B02, B06 and B12. Site B10 differs from these patterns by showing a uniquely high value on one date, Jan. 5. Crustal measurements are in the range of 1 to 7 $\mu g/m^3$; some of the differences among sites may be due to measurement uncertainty (about 0.2 to 2 $\mu g/m^3$).

- In the Corcoran area, all sites are related to factor 1. A second factor exists and is related to the contrast in patterns between COV and C08, on the one hand, and C11, C13, and C20, on the other. As noted above for the carbon measurements, sites C08, C15, C19, and COV have types "Residential" and "Industrial Waste" while sites C11, C13, and C20 are of type "Agricultural." Crustal measurements average 20-30 $\mu g/m^3$, which is well above detection limits. Differences between sites probably reflect real differences pertaining to different types of PM-generating activities, rather than artifacts due to measurement uncertainty.

- With only 5 dates available for analysis, several different combinations of the 9 available Fresno sites were considered. In all cases, all but three sites are significantly correlated with factor 1. Sites F23 and 28 are variously correlated with factor 1, factor 2 and both factors equally, depending on which other sites are included in the analyses. Site F35 is consistently correlated with factor 2; time series analysis shows that this site shows a much larger concentration increase from Jan. 4-5th than all other sites in this region. Crustal measurements range from about 1 to 7 $\mu g/m^3$, so that some of the differences among sites may be due to measurement uncertainty (about 0.2 to 2 $\mu g/m^3$).

- Two of the four Kern sites (K14 and K16) are explained by factor 1, one (K15) by factor 2, and one (K13) nearly equally by both factors. All of these measurements are in the range of 1 to 2 $\mu g/m^3$ range. The differences between sites are often no larger than the estimated measurement uncertainties.

In the four regions, factor 1 explains 55-79 percent of the variance of the crustal component.

For all saturation networks, all sites secondary-species concentrations correlate with factor 1, which explains 87-95 percent of the variance. The high loadings of all sites are consistent with the regional nature of secondary air pollutants.

CONCLUSION

In summary, the PCA shows;

- PM measurements at all sites within each network are highly correlated.

- Secondary pollutant measurements at all sites within each network are highly correlated.

- At Corcoran, the temporal patterns of carbon and crustal measurements appear to be related to site types and geographical proximity of sites.

- There are too few days of available data to draw conclusions for carbon and crustal measurements within the Bakersfield, Fresno, and Kern networks.

SECTION 5: SPATIAL REPRESENTATIVENESS OF SITES

OBJECTIVE

The spatial representativeness (SR) of a monitoring site may be loosely defined as the area within which pollutant concentrations are approximately constant. The objective of this task is to determine the spatial representativeness of core and other monitoring sites.

APPROACH

To determine SRs, gridded values were generated from the monitoring data. The interpolations were carried out for both the fall and winter saturation networks. The species analyzed were PM_{10} mass, the secondary component (sum of sulfate, nitrate, and ammonium), carbon (elemental plus organic), and the crustal component (the sum of aluminum, silicon, iron, manganese, calcium, and magnesium). The gridded values were then used to determine the portion of the monitoring domain having values within a specified percentage of those recorded at a given site.

METHODS

Spatial Interpolation

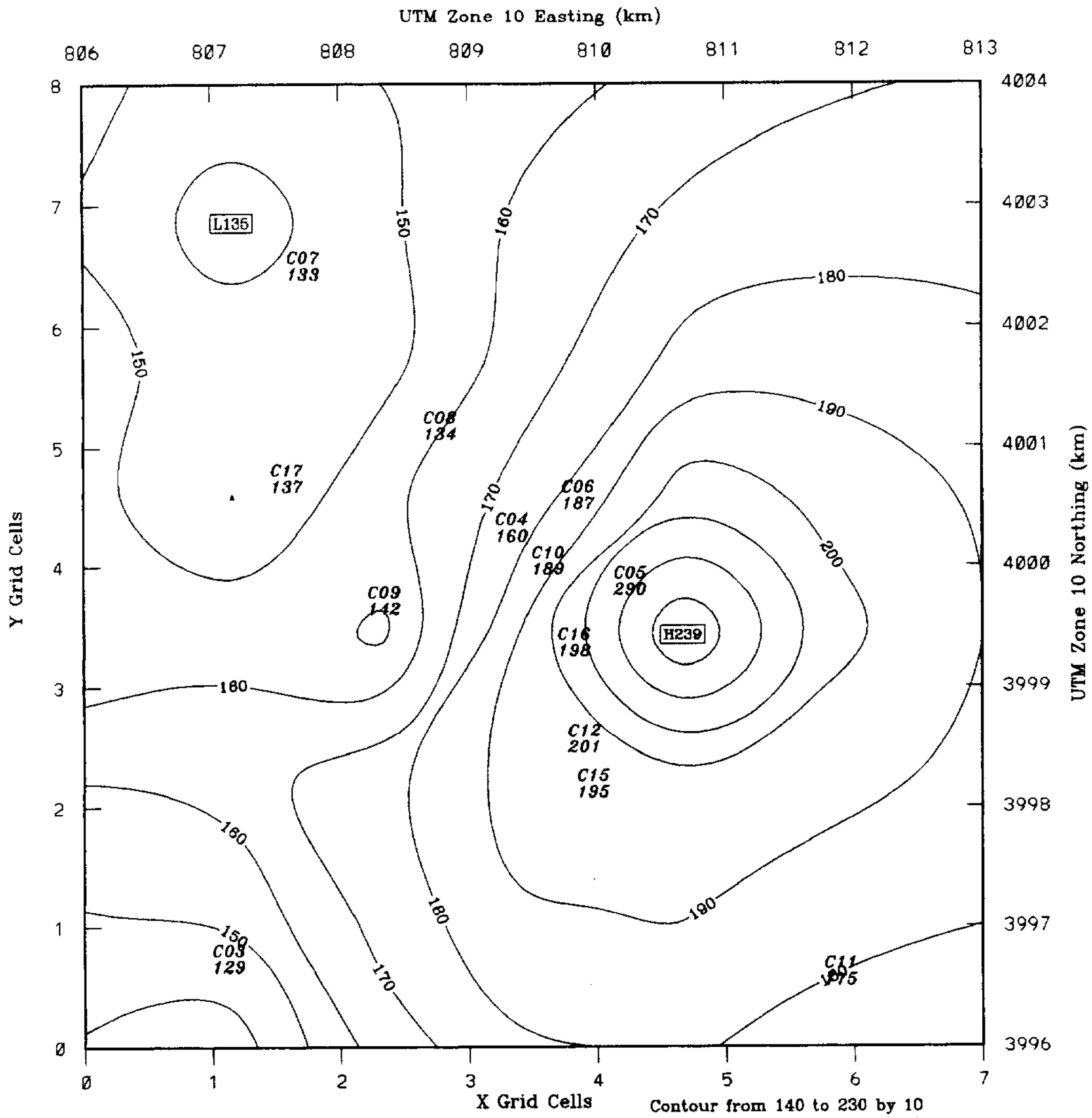
It was found that a grid resolution of 0.1 km was needed to correctly locate contours between closely spaced sites. For example, PM mass from the Corcoran saturation domain on November 13 was interpolated at grid sizes of 1.0 km, 0.5 km, 0.2 km and 0.1 km, with the results for the three most difficult to fit cells shown in Table 11. The values at C05 are too low, and those at C04 and C08 are too high. A grid size of 0.1 km was required to bring the C05 error below 5%. Figure 24a shows the contours resulting from the 1.0 km cell size. Site C05, with a measured value of 290 $\mu g/m^3$, falls on the 220 contour. Figure 24b shows the contours resulting from the 0.1 km cell size. Site C05 is now correctly valued by the contours, and the very high gradient to the west of the site is properly represented.

Table 11. Comparison of interpolated with actual values at three sites in the Corcoran saturation network.

Grid Spacing (km)	Difference Type (absolute or percent)	Interpolated minus measured value for Monitoring Site		
		C04	C05	C08
1.0	diff(μg/m^3)	16	-71	22
	% diff	10	-24	17
0.5	diff(μg/m^3)	7	-12	8
	% diff	4	-4	6
0.3	diff(μg/m^3)	6	-29	4
	% diff	4	-10	3
0.2	diff(μg/m^3)	5	-14	2
	% diff	3	-5	1
0.1	diff(μg/m^3)	1	-3	1
	% diff	0	-1	1

Definitions of Spatial Representativeness

Conceptually, the spatial representativeness of a monitoring site is the distance or area over which pollutant concentrations are similar to those occurring at the site in question. Expressed as a distance, spatial representativeness could be determined either as various radii for specified directions or sectors, or as an average radius. An areal definition of spatial representativeness could either require spatial continuity, or be determined as the total area of the domain that a site represents, independent of whether a simple boundary could be drawn around all this area (see operational definition 1 below). Spatial representativeness is a function of pollutant, direction, meteorology, and emissions activity. It may be determined for individual sites or for every grid cell in a domain, in which case it could be contoured like any other variable.

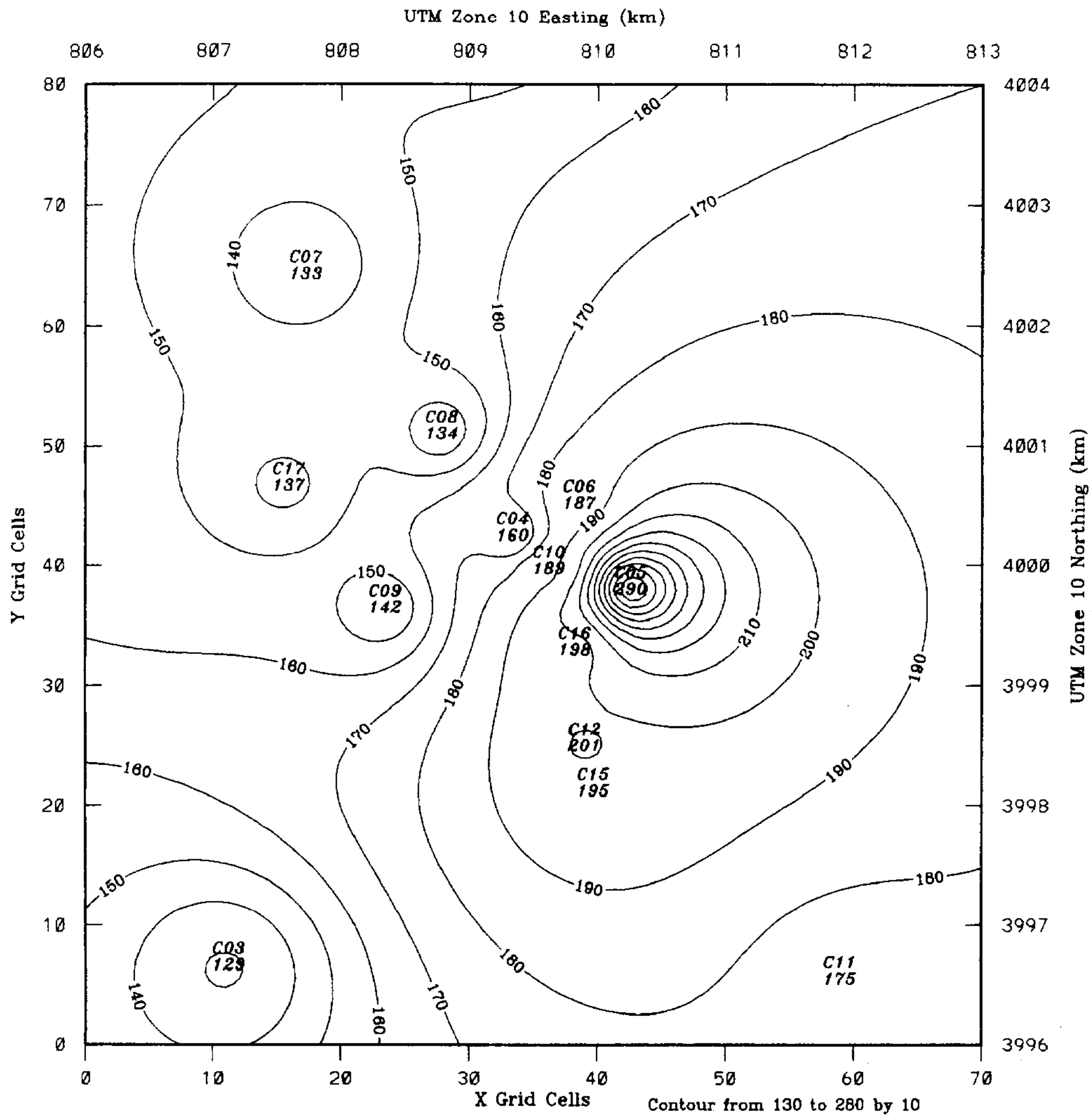


Corcoran Saturation Sites, Subdomain: cor2, dx = 1.0 km
Observations and Contours of Gridded PM10 Mass (ug/m3)
on Day 951113

IMS95 Data Analysis

Envair 31 Oct 1997 04:30

Figure 24a. Contour map of Corcoran saturation sites on November 13, 1995 with 1.0 km grid cells. Contour highs and lows are in square boxes. Site codes and measured values are in italics.



Corcoran Saturation Sites, Subdomain: cor2, dx = 0.1 km
Observations and Contours of Gridded PM10 Mass (ug/m3)
on Day 951113

IMS95 Data Analysis

Envair 22 Oct 1997 11:32

Figure 24b. Contour map of Corcoran saturation sites on November 13, 1995 with 0.1 km grid cells. Site codes and measured values are in italics.

More operationally, spatial representativeness is the area surrounding a site over which the concentration of a particular air pollutant changes less than some designated amount, specified either as a percentage or as a concentration. The domain must be large enough so that the concentration *does* change by the specified amount in all directions before reaching the edge of the domain. The largest spatial representativeness possible to determine within a given domain is the area of the domain or half the shorter dimension of a rectangular domain. The resolution will be on the order of half the distance between monitoring sites.

Three operational definitions are described below. The first defines SR by area; the second two define SR by distance from the site. The following steps are common to all the operational definitions:

- Grid the concentrations within the domain.
- Specify the percentage (Δ) or absolute (ϵ) change in concentration that defines spatial representativeness.
- If the SR criterion is expressed as a concentration, ϵ is the same for all sites or cells. If the SR criterion is expressed as a percentage, Δ, determine for each site or cell the concentration difference, ϵ, corresponding to Δ.

<u>Operational definition 1</u>

Sum the area of all grid cells whose absolute concentration difference from a given site is less than ϵ. The spatial representativeness of the site is then expressed as this area converted to a percentage of the total area of the domain. (The conversion from units of area to percentage of total domain area normalizes among domains of different sizes in the case of no spatial trend but must sometimes be reconverted to areal units to indicate actual physical extent). This definition is a simple method that captures the intuitive meaning of spatial representativeness for a small domain. It may also be readily expressed as "population representativeness" (PR), which is the percentage of the population of the domain that is represented by the site.

Operational definition 2

Search outward along the eight primary directions (N, NE, E, SE, S, SW, W, NW) until a cell is encountered with a difference from the site greater than ϵ. The distance to this cell is the spatial representativeness in that direction. These distances may be either specified separately or averaged. This method is computationally simple, because the cells form simple lines in the primary directions. A disadvantage is that, as distance from the site increases, so does the chance that a region different from the site will fall between two of the eight radiating lines. The following method remedies this disadvantage.

Operational definition 3

Rather than searching along the eight primary directions, examine concentric squares of grid cells, one by one, from the site outward. For each such square, when a cell in its outer boundary is encountered that has an absolute concentration difference greater than ϵ, determine the angle (theta) whose vertex is at the site and that exactly contains the cell. Along with the angle, determine the distance from the site to the inner (closest) edge of the cell in question. Eventually, distances and angles will have been determined covering a full circle around the site. If, in some direction, no cell is encountered having a concentration change greater than ϵ, then the distance to the border of the domain must be used. The average spatial representativeness as a radius is then computed as

$$\frac{1}{2\pi}\int_{\theta=0}^{2\pi} r\,d\theta,$$

where r is the distance along the angle θ to the inside edge of the appropriate square of cells. As an area, the computation is

$$\frac{1}{2}\int_{\theta=0}^{2\pi} r^2\, d\theta.$$

The integration is carried out piece by piece until the full circle is complete, or over appropriate sectors of interest. If h is the perpendicular distance from the site being analyzed to the inside edge of the appropriate side of the appropriate square of cells, then r=h sec θ. The indefinite integrals of interest are then

$$\int h \sec\theta\, d\theta = h \ln|\sec\theta + \tan\theta| \qquad \text{and} \qquad \frac{1}{2}\int h^2 \sec^2\theta\, d\theta = \frac{h^2}{2}\tan\theta.$$

While this method is conceptually similar to the previous one, it is difficult to program.

Choice of Operational Definition

We have chosen to use the first operational definition for the following reasons:

- A thorough evaluation of the relative virtues of these three definitions would involve the application of each of them to the project and a detailed comparison of the results. Such an analysis is beyond the resources of this effort.
- All three definitions would probably produce results substantially in agreement with each other.
- Definition 3 would generate a closed region of homogeneous concentration, since heterogeneities define the boundary. While such a region may appeal to an intuitive sense of spatial representativeness (a similar surrounding region), it is problematic because of the shadowing effect of small, nearby, heterogeneous regions. Definition 3 would be most appropriate to a large region, where the inclusion of distant grid cells would be inappropriate. (Since definition 2 is a

simplified approximation to definition 3, similar arguments apply.)

- Definition 1 is most pertinent to the question of how much of the area or population of each saturation region is represented by a given monitoring site.

Factors Affecting Spatial Representativeness

Relationship of Spatial Representativeness to Measurement Uncertainty

We characterize the spatial representativeness of a site in terms of the percentage of the monitoring domain that exhibits concentrations within a specified percentage, P, of the observed value at the site. This characterization is somewhat analogous to a regression equation. The usual regression situation attempts to discern a statistically significant trend line in a scatter of data. Here, instead, for a given observation, we determine how many others have values within a specified percentage, P, of the point in question. The answer depends upon the choice of P, the trend in the data (if any), and the variability of the observations around their trend line. The criterion P may be selected independently of the trend and measurement variability and should be equal to whatever value is thought to represent a meaningful difference. For example, a 20 percent difference between sites' measurements may, from the standpoint of characterizing potential health effects, be large enough to merit attention, whereas a one percent difference may not.

When observations are compared with each other, they may be found to differ by more than the percentage P. If so, the difference may arise from either the existence of a trend in the data (i.e., a spatial gradient) or from measurement variability. If the data had no trend and the measurement variability were of the order of P (i.e., one sigma measurement uncertainty was about equal to P), then, on average, about 50 percent of the observations would be within P (or one sigma) of any specified measurement. If, in addition to the measurement variability, a trend existed, fewer than 50 percent of the observations would fall within P percent of any given measurement.

If measurement variability were substantially larger than P (e.g., on the order of 20 percent compared to P = 5 percent), most observations would differ by more than P percent from most other observations. On the other hand, if measurement variability were small in comparison with P (e.g., 5 percent compared to P = 20 percent), the magnitude of the trend (if any) would determine how many observations fell within P percent of a given observation. If the trend exceeded P substantially, then fewer observations would be within P percent of a given observation than would be the case if the trend were much smaller than P.

As indicated, spatial representativeness is a function of both measurement uncertainty and spatial trends. In general, this is a desirable feature of spatial representativeness, because measurements with large uncertainty are less spatially representative. If, however, we want a measure of how well a site represents a larger area, independent of measurement uncertainty, we can do it only by minimizing measurement uncertainty. Measurement variability can be minimized by the use of multiple replicate samplers at each site. Computing spatial representativeness from the mean concentrations occurring over a period of time (e.g., a 30-day average of daily measurements) would also minimize measurement variability, but only at the cost of including temporal variability, which may be even larger.

By generating multiple realizations without superimposed temporal variability, a Monte Carlo exercise could be used to investigate the difference between SR due to true domain variability and that produced by measurement uncertainty. The procedure would be to assume one or more true concentration fields and then calculate the spatial representativeness of the sites. How well this procedure would actually work would depend on how large an uncertainty the average spatial representativeness of each site had and how dependent the result was on the choice of the "true" concentration field.

Uncertainty of spatial representativeness

The uncertainty of our spatial representativeness calculations can be defined by the following imaginary procedure. First, for a particular saturation region, repeat a particular day's measurements a large number of times. Each set of measurements is a realization of the experiment. From each realization, produce a gridded concentration field (just as we have done from our single actual realization). Then repeat the spatial representativeness calculations for each of these fields. The distribution of the resulting set of spatial representativenesses would provide us with a measure of the uncertainty of spatial representativeness. This uncertainty would increase as the measurement uncertainty increased, because the variability of the gridded fields would increase, but it would decrease as more sites were involved in producing the gridded fields.

How the uncertainty of spatial representativeness is affected by the choice of the criterion of spatial representativeness is suggested by Figure 43 (found later in this section), which shows the time series of mean SR using SR criteria ranging from 1% to 50%. Such a time series is an approximation of repeated experimental realizations, even though temporal variability is superimposed and increases the apparent uncertainty of spatial representativeness. We see from this figure that the variability of spatial representativeness is at a maximum when spatial representativeness is about 50%. In this figure, maximum variability occurs for a SR criterion of 10%. This variability is clearly not monotonically related to the SR criterion, since the least variable spatial representativenesses occur at the highest and the lowest criteria.

Choice of spatial representativeness criterion

We have chosen to use a twenty percent change of concentration as our criterion for spatial representativeness because:

- As explained above, the criterion may be selected independently of the trend and measurement variability and should be equal to whatever value is thought to represent a meaningful difference. A 20 percent difference between sites' measurements may, from the standpoint of characterizing potential health effects, be large enough to merit attention, whereas a one percent difference may not.

- Twenty percent differences usually exceed measurement error for days having higher PM concentrations. If a site measured 150 $\mu g/m^3$, its spatial representativeness would encompass cells ranging in concentration from 120 to 180 $\mu g/m^3$. For 50 $\mu g/m^3$, the range would be from 40 to 60 $\mu g/m^3$.
- The use of concentration rather than percent as a criterion is problematic because spatial representativeness based on concentration is so strongly anti-correlated with concentration. This phenomenon is discussed further in the subsection on "Sensitivity Analyses" (found later in this section).

RESULTS

Spatial Representativeness of Saturation Sites

The results of the spatial representativeness calculations for PMT using a 20% criterion are presented in Tables 12-15 for Corcoran, Fresno, Kern, and Bakersfield, respectively. Similar results for CRU are in Tables 16-19, for SEC in Tables 20-22, and for CAR in Tables 23-25. There are no spatial representativeness values in the Kern domain for SEC and CAR because these parameters were measured for one site only. Numbers were rounded to integers for compact presentation. Missing data are indicated by -99.

To interpret these tables, we first present some examples. Table 12 shows that site C04 on November 13 has a spatial representativeness of 99%. This means that 99% of the area of the Corcoran saturation domain had a concentration within 20% of that of C04. Referring back to Figure 21, which shows PMT concentration isopleths for a portion of the Corcoran saturation domain on November 13 [1], we see that site C04 had a PM_{10} concentration of 160 μg/m^3. Table 12 therefore indicates that 99% of the domain had concentrations in the range 160 μg/m^3 ± 20%, or between 128 and 192 μg/m^3. As a second example, on November 13 site C03 has a spatial representativeness of 15%, meaning that 15% of the area of the domain has concentrations in the range of 129μg/m^3±15% or between 110 and 148 μg/m^3. The last column in each table shows the average spatial representativeness of each site over all the days for which there are data. For example, C04, which is collocated with the core site, has an average representativeness of 87%, indicating it is among the most representative sites in the region and therefore a good location for the core site (we discuss this issue further below). The last row in each table is the average spatial representativeness over all the sites in the region on each day, and therefore shows how region-wide representativeness changes with time (more also on this below).

Two of the closest sites in the Corcoran domain, C05 and C06, located about 1 km apart, show the minimum and maximum representativeness, respectively, for PM and crustal material (C05 also shows the minimum for carbon). Although both are situated along the railroad tracks on the east side of town, C05 is clearly influenced by a localized PM source.

The collocated samplers B01 and B12 often show different spatial representativeness, thus indicating the influence of sampler accuracy on the results. On some days (e.g., PM mass on January 3), a low SR at B01 and a high value at B12 may be seen to coincide with a deviation of B01 from B12 and the collocated sequential filter sampler (see Appendix A).

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[1] Note that Figure 21 is only eight percent of the Corcoran saturation domain. This subdomain was illustrated to show the compact central cluster of monitoring sites.

Table 12. Corcoran spatial representativeness (20% criterion) of PMT as a percentage of the total domain area.

	Date (November 1995)														
stc	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Avg
C01	99	42	99	100	100	9	77	93	73	81	98	95	95	93	82
C02	89	33	66	99	93	95	1	96	89	4	2	3	13	32	51
C03	98	89	99	90	98	93	97	97	16	6	94	93	15	42	73
C04	8	67	100	95	99	88	97	99	99	86	97	88	99	100	87
C05	0	22	3	0	0	13	10	1	0	94	3	2	0	0	11
C06	95	90	100	85	99	89	-99	95	98	39	98	-99	92	100	90
C07	7	17	100	99	0	96	94	98	85	4	98	83	23	6	58
C08	91	86	100	100	100	97	97	99	100	93	98	90	27	97	91
C09	61	83	100	99	97	-99	97	100	79	96	96	56	82	99	88
C10	91	84	100	97	99	13	89	95	99	98	80	94	90	100	88
C11	86	57	100	99	99	97	2	100	64	97	98	17	98	100	79
C12	75	0	100	99	3	95	55	99	98	78	14	10	72	100	64
C13	45	89	100	100	97	95	93	99	96	78	7	93	94	100	85
C14	23	89	99	100	97	90	70	5	48	89	97	95	79	-99	75
C15	28	91	100	95	99	71	79	98	99	98	91	0	83	99	81
C16	97	86	100	98	81	97	9	97	99	97	96	2	80	89	81
C17	2	61	100	99	99	94	94	99	90	88	95	2	49	97	76
C18	80	1	100	7	99	88	76	99	99	14	98	1	88	89	67
C19	94	90	100	100	99	22	96	100	46	94	92	58	80	100	84
C20	90	77	100	97	50	83	9	96	95	93	0	93	27	98	72
C21	27	84	100	76	96	17	1	89	61	41	97	95	5	86	62
C22	-99	-99	-99	86	100	9	90	99	77	98	8	77	99	100	77
Avg	61	64	94	87	82	69	63	89	78	71	71	55	63	82	74

Table 13. Fresno spatial representativeness (20% criterion) of PMT as a percentage of the total domain area.

Date (December 1995 and January 1996)

stc	9	10	11	12	13	14	15	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	Avg
F18	85	-99	65	0	93	1	69	68	45	72	91	25	11	74	7	4	97	94	1	93	90	60	76	20	74	28	54
F19	83	99	90	80	-99	8	75	91	94	64	47	66	77	72	55	83	87	0	89	93	95	89	17	83	86	-99	72
F20	-99	34	88	2	0	63	57	53	0	31	93	6	10	26	6	0	90	2	78	72	11	16	0	80	87	68	39
F21	28	52	1	76	2	29	22	60	68	21	94	9	8	24	10	23	91	0	83	90	95	40	0	68	98	53	44
F22	71	76	84	89	94	15	91	0	89	87	92	66	67	61	48	74	79	-99	90	40	85	90	75	52	94	92	72
F23	4	0	18	2	78	11	0	73	86	75	93	78	60	73	59	1	96	78	11	78	96	89	79	75	98	93	58
F24	-99	86	91	83	40	0	89	93	91	80	93	12	11	34	48	85	65	88	89	73	0	64	75	15	-99	78	62
F25	75	98	1	92	92	30	63	85	2	83	66	59	-99	0	69	30	99	79	8	99	50	86	61	7	96	64	60
F26	15	99	31	6	67	1	90	88	67	0	0	55	42	6	-99	1	7	94	27	-99	92	10	19	9	54	18	37
F27	1	88	86	65	-99	61	91	45	51	12	2	15	18	12	5	9	98	8	7	1	48	37	77	54	-99	79	40
F28	-99	94	86	73	17	13	77	21	83	81	92	22	1	76	57	89	91	90	86	62	64	83	7	68	95	86	65
F29	-99	91	89	10	95	46	81	56	91	83	2	70	29	58	43	87	6	71	71	93	84	73	0	68	89	-99	62
F30	85	94	79	91	18	49	60	64	14	17	-99	3	68	65	44	6	22	2	28	83	90	69	4	10	10	-99	45
F31	69	86	83	72	93	64	29	64	10	29	90	69	10	0	29	77	0	16	82	78	38	46	4	7	97	30	49
F32	-99	90	64	5	1	55	84	0	2	85	89	-99	28	32	24	90	86	0	84	-99	35	73	62	34	84	75	51
F33	72	41	0	92	-99	37	91	89	89	0	92	72	7	8	70	62	99	94	95	87	-99	79	35	49	-99	93	63
F34	3	70	36	89	86	2	2	46	26	5	74	7	5	7	5	76	96	26	93	32	56	5	5	6	84	6	36
F35	2	85	80	69	71	9	36	71	-99	80	94	45	32	6	15	91	98	93	92	98	58	85	71	17	98	19	61
F36	11	9	49	4	37	40	7	61	7	8	94	0	3	7	4	81	94	9	92	-99	23	7	24	7	72	12	31
F38	42	98	45	87	69	25	7	58	62	86	95	5	83	35	-99	43	97	89	74	1	27	75	0	3	98	93	56
F39	84	98	65	93	1	3	24	79	61	6	17	17	8	10	-99	6	27	95	67	95	89	32	1	83	88	71	49
F40	77	97	90	5	22	5	73	97	89	42	21	2	7	0	11	62	98	94	86	14	0	59	78	-99	2	-99	47
F41	32	2	88	86	0	60	59	68	37	73	84	24	19	22	37	19	94	34	88	80	60	70	24	76	98	51	53
F42	77	97	79	92	0	5	-99	25	92	87	92	70	76	28	23	-99	4	90	0	99	75	0	73	78	90	55	59
F43	67	91	45	86	58	37	59	75	85	82	71	70	36	43	-99	85	2	79	92	97	44	86	42	0	23	86	62
Avg	49	74	61	58	47	27	56	61	56	52	70	36	30	31	32	49	69	55	64	71	59	57	36	40	78	59	53

Table 14. Kern spatial representativeness (20% criterion) of PMT as a percentage of the total domain area.

Date (December 1995 and January 1996)

stc	9	10	11	12	14	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	Avg
K13	72	64	91	100	60	28	100	90	73	60	80	87	76	10	90	84	66	84	96	13	71	100	100	66	73
K14	100	93	94	100	94	99	98	-99	86	-99	-99	3	67	90	92	84	76	26	100	22	68	100	100	57	79
K15	100	20	92	100	96	86	85	100	74	51	55	84	25	88	89	32	55	100	100	-99	67	100	100	47	76
K16	100	93	95	-99	-99	98	100	-99	97	50	75	91	50	88	93	86	8	89	100	67	2	100	85	48	77
K17	100	93	4	100	95	95	81	47	5	62	3	81	-99	93	3	77	30	-99	100	4	-99	-99	100	62	62
Avg	94	73	75	100	86	81	93	79	67	56	53	69	55	74	73	73	47	75	99	26	52	100	97	56	73

Table 15. Bakersfield spatial representativeness (20% criterion) of PMT as a percentage of the total domain area.

	Date (December 1995 and January 1996)																								
stc	9	10	11	12	13	14	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	Av
B01	86	10	80	-99	0	-99	69	46	96	80	20	33	44	47	78	-99	87	17	83	2	78	8	95	38	71	53
B02	89	71	78	3	5	8	46	99	84	50	52	2	45	38	61	98	80	89	63	75	2	-99	91	68	78	57
B03	89	60	74	-99	-99	86	83	89	92	79	27	17	9	-99	85	85	88	79	60	20	83	3	95	46	78	65
B04	59	1	73	66	5	11	81	96	90	45	1	37	40	46	77	92	74	74	79	45	65	3	79	57	84	55
B05	61	5	38	57	76	86	60	98	92	84	54	1	10	17	76	26	73	7	2	29	80	47	91	34	55	50
B06	2	87	85	24	43	5	79	93	97	80	70	-99	6	85	26	74	83	1	5	8	81	73	3	3	94	50
B07	5	84	86	73	76	0	-99	100	97	80	65	61	65	58	91	100	65	90	91	-99	83	8	95	80	88	71
B08	86	13	3	4	6	85	92	100	9	3	4	24	2	7	4	-99	5	-99	-99	5	4	3	93	23	6	26
B09	85	54	88	-99	64	86	80	42	97	69	0	53	68	56	88	100	87	90	-99	59	80	-99	95	11	94	70
B10	11	19	89	54	56	84	0	100	92	83	12	5	42	78	88	85	90	79	79	74	83	76	93	88	92	66
B11	89	80	64	7	41	86	85	100	86	87	6	38	2	-99	83	88	84	82	42	39	0	63	95	74	-99	62
B12	80	59	88	63	7	-99	79	99	94	70	28	1	0	87	83	89	92	49	88	74	83	11	94	41	94	65
Avg	62	45	71	39	35	54	69	88	86	67	28	25	28	52	70	84	76	60	59	39	60	29	85	47	76	58

Table 16. Corcoran spatial representativeness (20% criterion) of CRU as a percentage of the total domain area.

	Date (November 1995)									
stc	6	7	8	9	10	11	12	13	14	Avg
C03	93	77	98	10	17	94	96	23	5	57
C05	1	1	2	0	94	1	53	0	1	17
C06	81	-99	86	97	93	90	-99	86	99	90
C08	94	94	98	98	99	91	96	10	20	78
C09	-99	95	95	34	99	94	96	44	97	82
C11	92	0	98	88	100	93	2	91	99	74
C13	90	94	98	92	79	8	92	86	100	82
C15	11	84	91	96	98	47	0	70	97	66
C19	5	95	66	9	61	93	79	7	99	57
C20	94	3	4	98	86	1	3	8	100	44
Avg	62	60	74	62	83	61	57	42	72	65

Table 17. Fresno spatial representativeness (20% criterion) of CRU as a percentage of the total domain area.

	Date (December 1995 and January 1996)				
stc	26	27	4	5	6	Avg
F18	2	2	5	5	11	5
F19	5	9	47	0	-99	15
F20	68	0	32	48	46	39
F21	76	76	10	20	75	51
F22	79	70	69	75	79	74
F23	41	1	55	53	53	40
F24	50	43	70	-99	80	61
F25	30	4	7	12	17	14
F26	-99	2	30	7	7	12
F27	19	56	39	-99	60	44
F28	45	71	16	75	41	50
F29	21	7	16	20	-99	16
F30	5	3	0	3	47	12
F31	3	38	3	61	3	22
F32	49	18	51	70	36	45
F33	19	79	44	-99	81	56
F34	9	20	4	6	19	12
F35	37	50	26	5	0	24
F36	1	4	1	1	5	2
F38	-99	33	2	27	81	36
F39	-99	0	10	10	1	5
F40	61	68	-99	75	-99	68
F41	79	72	20	31	71	55
F42	22	-99	21	23	80	36
F43	-99	24	4	12	72	28
Avg	34	31	24	29	44	33

Table 18. Kern spatial representativeness (20% criterion) of CRU as a percentage of the total domain area.

	Date (December 1995 and January 1996)					
stc	26	27	4	5	6	Avg
K13	100	100	100	96	68	93
K14	100	84	100	99	48	86
K15	100	94	100	39	55	78
K16	100	84	99	86	15	77
K17	-99	33	-99	100	88	74
Avg	100	79	100	84	55	81

Table 19. Bakersfield spatial representativeness (20% criterion) of CRU as a percentage of the total domain area.

	Date (December 1995 and January 1996)					
stc	26	27	4	5	6	Avg
B01	73	56	78	44	64	63
B02	38	35	42	24	14	31
B03	-99	44	47	55	67	53
B04	25	56	7	52	61	40
B05	51	83	74	24	19	50
B06	21	22	1	5	17	13
B07	55	53	74	58	77	63
B08	4	3	7	2	3	4
B09	68	57	74	3	71	55
B10	6	42	76	1	44	34
B11	-99	71	77	57	-99	68
B12	29	83	59	55	39	53
Avg	37	51	51	32	43	44

Table 20. Corcoran spatial representativeness (20% criterion) of SEC as a percentage of the total domain area.

	Date (November 1995)									
stc	6	7	8	9	10	11	12	13	14	Avg
C03	40	61	99	75	73	43	100	100	100	77
C05	87	100	100	100	93	94	63	100	100	93
C06	-99	-99	77	9	89	97	-99	100	100	79
C08	94	-99	100	97	98	84	100	100	100	97
C09	-99	-99	100	96	82	93	-99	100	100	95
C11	79	-99	100	100	93	95	100	100	100	96
C13	78	98	100	98	64	100	-99	100	100	92
C15	80	89	100	99	91	96	100	100	100	95
C19	57	-99	100	-99	52	39	99	100	100	78
C20	4	-99	100	17	29	96	97	100	100	68
Avg	65	87	98	77	76	84	94	100	100	87

Table 21. Fresno spatial representativeness (20% criterion) of SEC as a percentage of the total domain area.

	Date (December 1995 and January 1996)				
stc	26	27	4	5	6	Avg

stc	26	27	4	5	6	Avg
F24	18	78	94	-99	99	72
F27	97	99	98	-99	99	98
F28	81	85	97	99	100	92
F29	93	98	98	96	-99	97
F30	58	1	97	100	100	71
F31	17	96	97	98	-99	77
F32	93	98	86	98	4	76
F33	36	95	1	-99	100	58
F35	35	49	96	16	100	59
F38	-99	33	98	-99	99	77
F39	-99	94	2	69	99	66
F40	93	97	-99	97	-99	96
F41	80	99	98	3	-99	70
Avg	64	79	80	75	89	78

Table 22. Bakersfield spatial representativeness (20% criterion) of SEC as a percentage of the total domain area.

Date (December 1995 and January 1996)

stc	26	27	4	5	6	Avg
B01	100	99	-99	95	-99	98
B04	100	84	98	96	-99	94
B05	100	84	62	99	-99	86
B07	100	0	54	97	100	70
B09	100	90	95	3	100	78
B10	100	97	87	97	100	96
B12	100	12	41	99	100	70
Avg	100	67	73	84	100	85

Table 23. Corcoran spatial representativeness (20% criterion) of CAR as a percentage of the total domain area.

	Date (November 1995)									
stc	6	7	8	9	10	11	12	13	14	Avg
C03	30	95	1	34	0	9	88	3	1	29
C05	0	0	19	0	0	10	7	0	0	4
C06	68	-99	94	47	17	16	-99	6	99	49
C08	12	74	96	90	98	86	37	93	99	76
C09	-99	93	99	89	93	70	15	17	98	72
C11	74	48	43	75	24	80	88	38	96	63
C13	11	91	98	59	72	4	1	93	99	59
C15	46	95	99	85	88	86	48	64	99	79
C19	16	6	99	4	98	19	77	86	99	56
C20	35	95	99	68	69	3	83	2	60	57
Avg	32	66	75	55	56	38	49	40	75	54

Table 24. Fresno spatial representativeness (20% criterion) of CAR as a percentage of the total domain area.

	Date (December 1995 and January 1996)					
stc	26	27	4	5	6	Avg
F24	51	96	95	-99	92	84
F27	3	15	77	-99	5	25
F28	10	86	86	17	92	58
F29	85	93	98	37	-99	78
F30	82	90	26	68	80	69
F31	74	85	96	37	91	76
F32	21	91	91	79	92	75
F33	72	63	0	-99	3	34
F35	2	5	73	1	7	18
F38	-99	95	90	-99	15	67
F39	-99	20	95	92	86	73
F40	2	3	-99	50	-99	18
F41	17	21	91	75	-99	51
Avg	38	59	77	51	56	56

Table 25. Bakersfield spatial representativeness (20% criterion) of CAR as a percentage of the total domain area.

	Date (December 1995 and January 1996)					
stc	26	27	4	5	6	Avg
B01	61	58	0	22	-99	35
B04	23	4	63	11	-99	25
B05	7	34	6	2	-99	12
B07	96	0	58	82	80	63
B09	30	89	90	71	91	74
B10	94	96	11	12	4	43
B12	93	96	87	45	33	71
Avg	58	54	45	35	52	46

Spatial Representativeness of Core Sites

A saturation site was collocated with the core site in each saturation region. These were C04, F21, B12, and K14. Figures 25-28 show the spatial representativeness of these sites and their concentrations of PMT. In addition to spatial representativeness, the figures also show population representativeness, which is the percentage of the domain population that is within the area of spatial representativeness. The population representativeness generally tracks the spatial representativeness rather well. The exception is a few days in Fresno.

C04 is highly representative of the saturation region, except for November 1, improving considerably on the average spatial representativeness of all the sites. F21 is sometimes very representative and more often quite unrepresentative. Both B12 and K14 are often quite representative and occasionally very unrepresentative. Since the representativeness of the core sites seems to vary so greatly, their representativeness is best expressed as a percentage of the time that their spatial representativeness exceeds some level, such as 75%. By this criterion, C04 is representative 86% of the time, F21 is representative 27% of the time, K14 is representative 72% of the time, and B12 is representative 60% of the time. Population representativeness for F21 is 50%, indicating that it represents substantially more of the population of the domain than the area.

The core sites' representativeness fluctuates considerably (C04 is the exception). Their representativeness is often, but not always, high when concentrations are high (exceptions occur, such as F21 on Dec. 26, which has low representativeness and high concentration). In this data set, therefore, it is possible to identify exceedance conditions throughout much of the monitoring domains with fewer monitors. However, the actual number of exceedances may be much greater at a site that is strongly influenced by a local source than at the core or most other sites. For example, as noted in Section 2, site C05 showed higher PM concentrations than did other Corcoran sites. The core site exceeded 150 μg m^{-3} on three of 14 days, while C05 exceeded that level on the same three plus an additional eight days. Other purposes, such as model evaluation, identification of a domain maximum, or computation of population exposure, may also necessitate the use of a larger network.

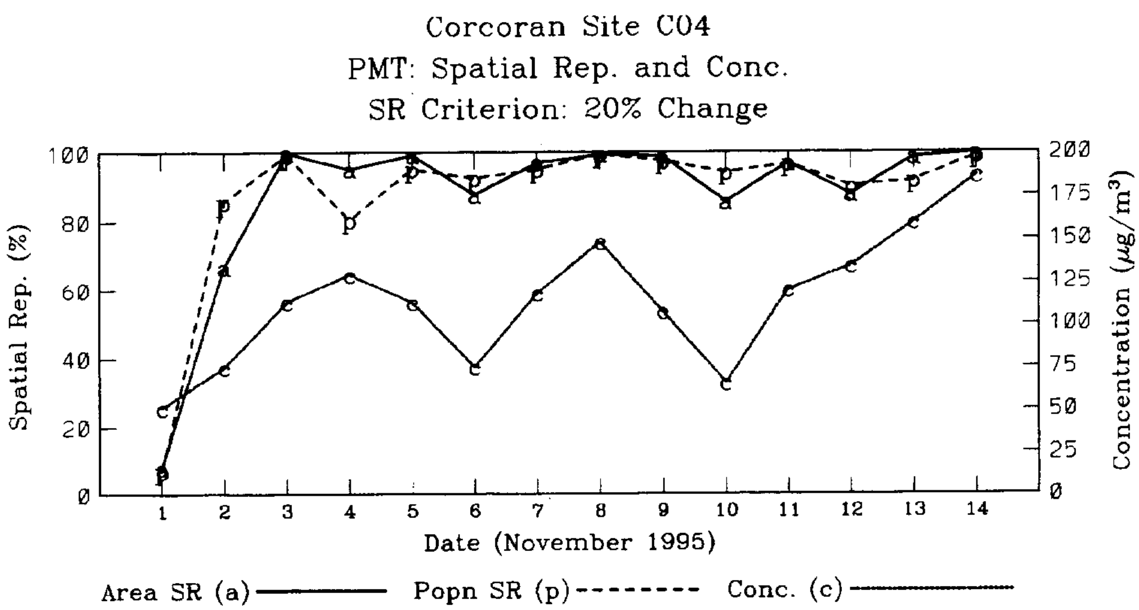
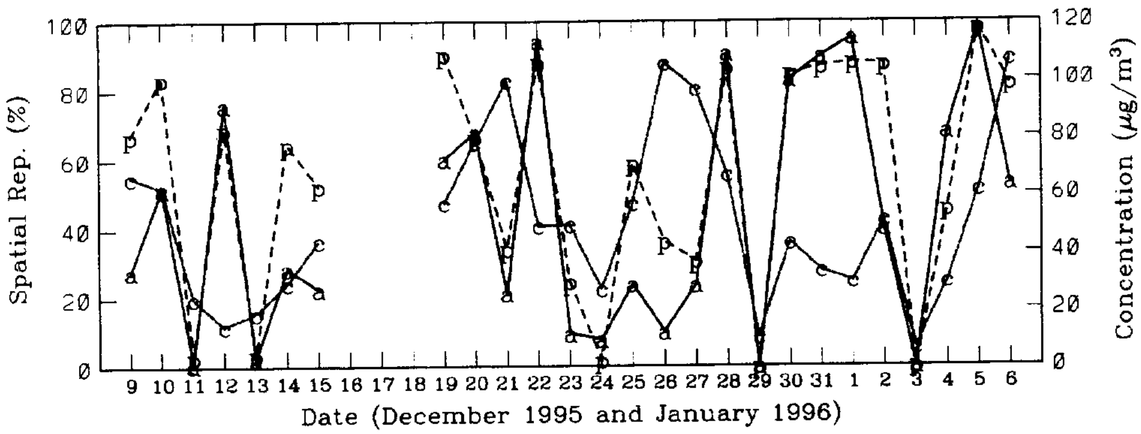


Figure 25. Spatial representativeness and PM_{10} at site C04 (collocated with Corcoran core), November 1995.

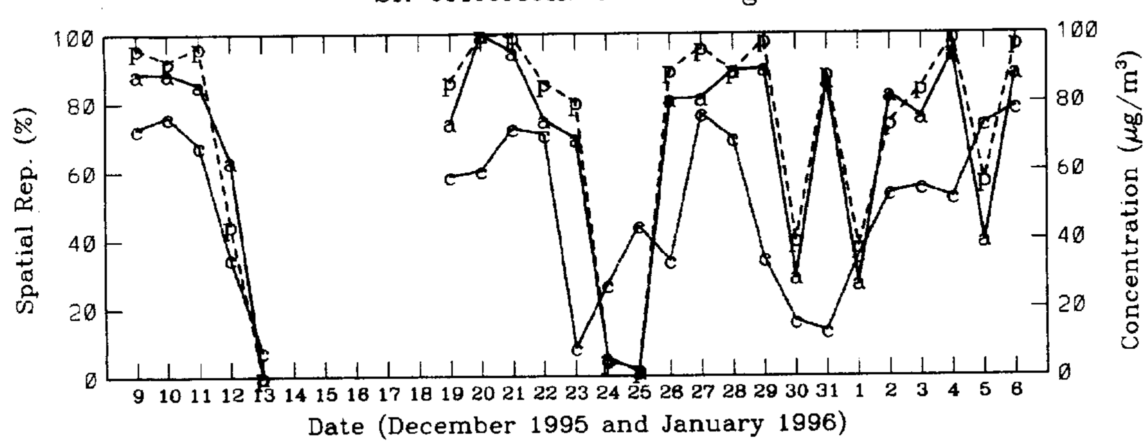
Fresno Site F21
PMT: Spatial Rep. and Conc.
SR Criterion: 20% Change



Area SR (a) ——— Popn SR (p) - - - - - - - - Conc. (c) ———

Figure 26 Spatial representativeness and PM_{10} at site F21 (collocated with Fresno core), December 1995 and January 1996.

Bakersfield Site B12
PMT: Spatial Rep. and Conc.
SR Criterion: 20% Change



Area SR (a) ——— Popn SR (p) - - - - - - - - Conc. (c) ———

Figure 27. Spatial representativeness and PM_{10} at site B12 (collocated with Bakersfield core), December 1995 and January 1996.

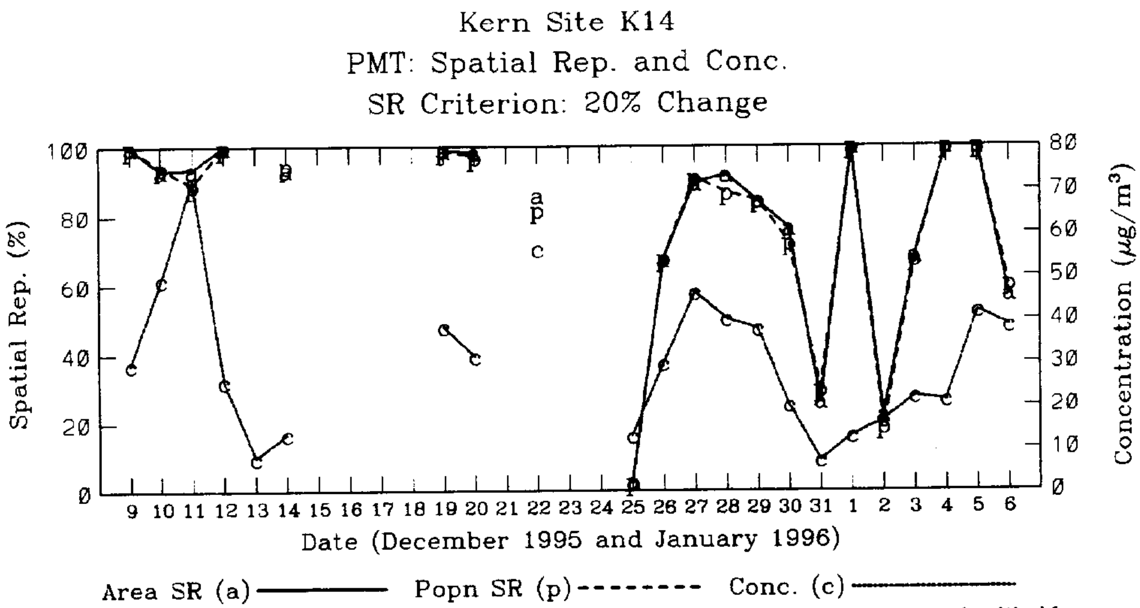


Figure 28. Spatial representativeness and PM_{10} at site K14 (collocated with Kern core), December 1995 and January 1996.

Table 26 shows, for each of four locations, the percentage of days having spatial representativeness >75%, both for all measurements and for those with measured values of PMT > 50 μg/m³.

Table 26. Percent of days having spatial representativeness > 75%

Site	All measurements	PMT > 50 μg/m³
C04	12/14 = 86%	12/14 = 86%
F21	7/26 = 27%	2/12 = 17%
B12	15/25 = 60%	12/14 = 86%
K14	18/25 = 72%	2/2 = 100%

The representativeness of sites B12 and K14 improved when days were restricted to those with PMT > 50 μg/m^3, but F21's performance declined.

Mean Spatial Representativeness

The mean representativeness provides a way to examine the domain-wide pattern of spatial representativeness with the smaller uncertainty that results from averaging. Figures 29 through 32 show the mean spatial representativeness (obtained from the bottom rows of Tables 14-18) and mean concentration of PMT for each saturation network. The SR criterion is 20%. Also shown on these displays is "population representativeness" (PR), the percentage of the total domain population present in the represented area. Similar displays for CRU, SEC, and CAR are shown on Figures 33-36, 37-39 and 40-42. These figures show that mean population representativeness and mean spatial representativeness track each other closely. The following discussion emphasizes PMT time series, because CRU, SEC, and CAR were analyzed on far fewer days at fewer sites.

The plots show large fluctuations in mean spatial representativeness that have the same period as the fluctuations in mean concentration. The troughs of SR generally lag the troughs of concentration. This lag is from one to three days and can be seen in Corcoran (Figure 29), Fresno (Figure 30), and in the second two troughs in Bakersfield (Figure 32). In the first portion of the Bakersfield record, the fluctuations of spatial representativeness and concentration are temporally matched. The peaks of spatial representativeness show a more varied pattern: they may lead, lag, or be coincident with the concentration peaks. The first Corcoran peak leads by a day; the second is coincident. In Fresno, the peak on December 22 lags by a day; the broad peak from the 28th to the 31st lags from 1 to 4 days. This broad peak almost appears anti-correlated with concentration, but examination of the overall pattern indicates that it is a lag. The following scenario, which requires testing, could account for the pattern:

1. Begin with clean air or background concentrations. At this stage, areas around sources are (in percentage terms), much higher than surrounding areas. Spatial representativeness of sites near sources is low.

2. Low mixing conditions develop (low winds and low mixing heights). PM buildup begins.

3. After a day or two, spatial representativeness becomes even lower, because mixing is low, so the buildup is localized to source areas, and the contrast between the area around sources and background becomes even higher. So while domain-wide PM concentrations have risen, spatial representativeness has decreased further. Thus, the trough of spatial representativeness lags the trough of PM.

4. Then, even with low mixing, PM spreads out from sources, and domain-wide levels rise. The percentage difference between the background and source areas decreases, and spatial representativeness increases.

5. Continued domain-wide increases in concentration continue to diminish the contrast between background and source areas, so spatial representativeness and concentration continue to rise together.

6. At the peak there are three cases: spatial representativeness may lag, be coincident with, or lead the peak of concentration.

   a. Spatial representativeness could lag concentration if mixing heights and vertical mixing increased while horizontal winds remained low, thus diluting the concentration while maintaining or increasing its homogeneity. See Fresno December 21-22 and 28-31 (Figure 30) and Bakersfield December 27-28 (Figure 32).

   b. Spatial representativeness and concentration could decrease together if external air mixed into the domain in an uneven manner, from one side, for example. Domain mean concentration and homogeneity would both decrease. Examples are December 10 in Fresno and November 8 in Corcoran.

c. Spatial representativeness could decrease while concentration continues to increase if small amounts external air mix unevenly into the domain, decreasing spatial representativeness while domain-wide mean concentration continues to increase. When this case occurs, the decrease in spatial representativeness is fairly small prior to the subsequent fall of concentration. Examples are December 20-21 in Bakersfield and November 3-4 in Corcoran.

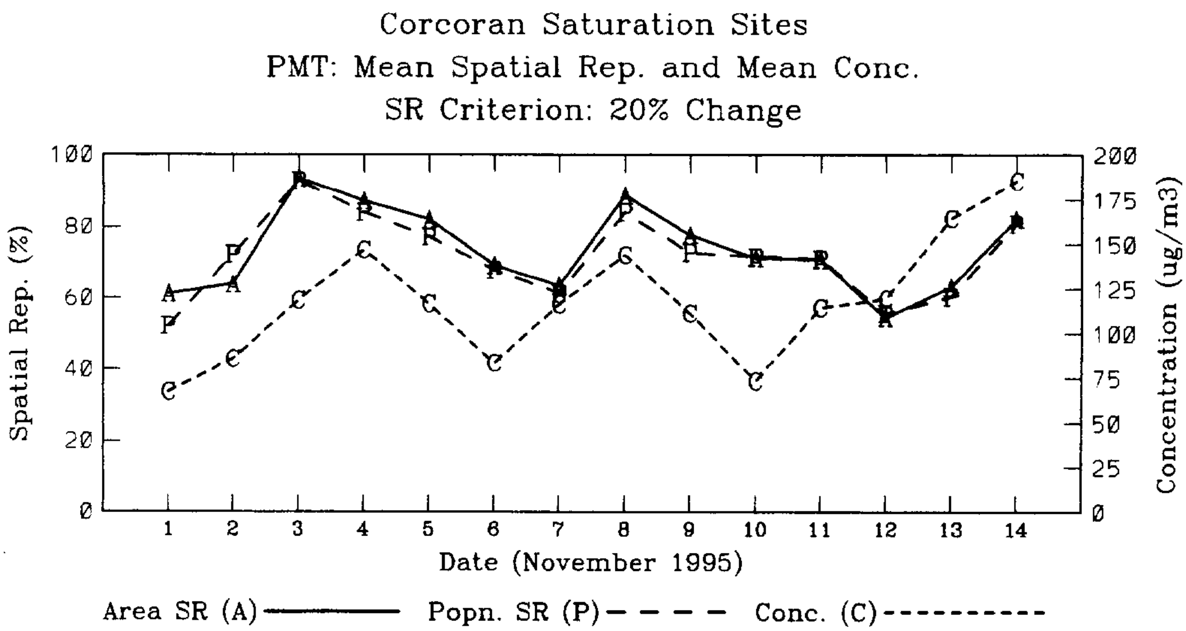


Figure 29. Mean spatial representativeness and concentration of PM_{10} for Corcoran sites, November 1995.

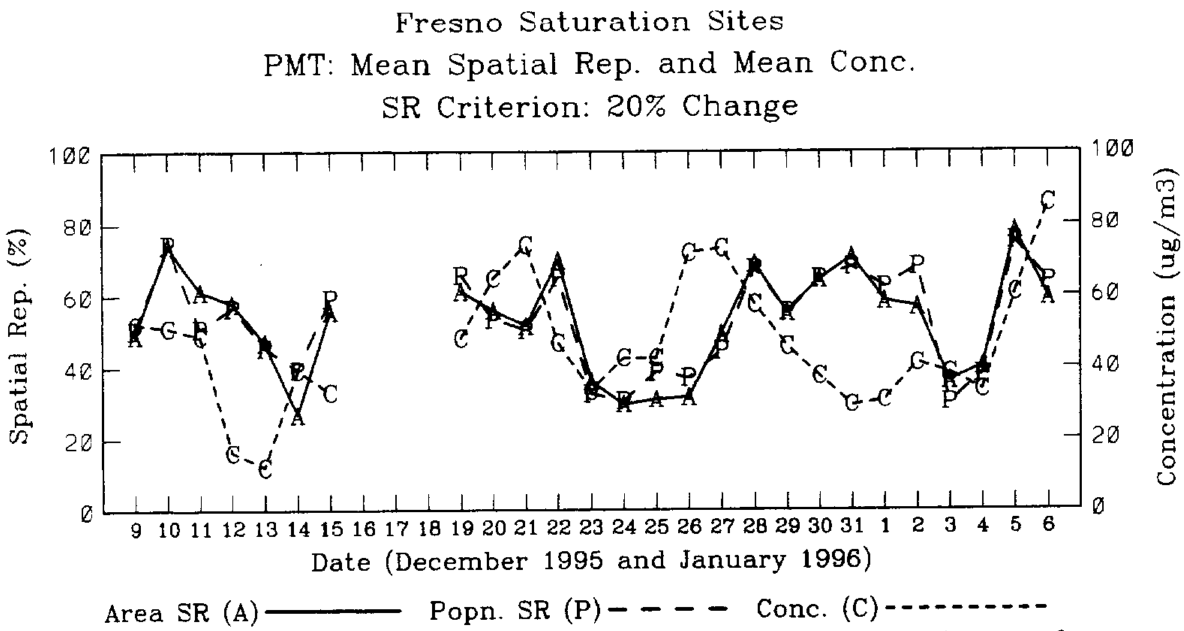


Figure 30. Mean PM_{10} concentration and average spatial representativeness for Fresno, December 1995 and January 1996.

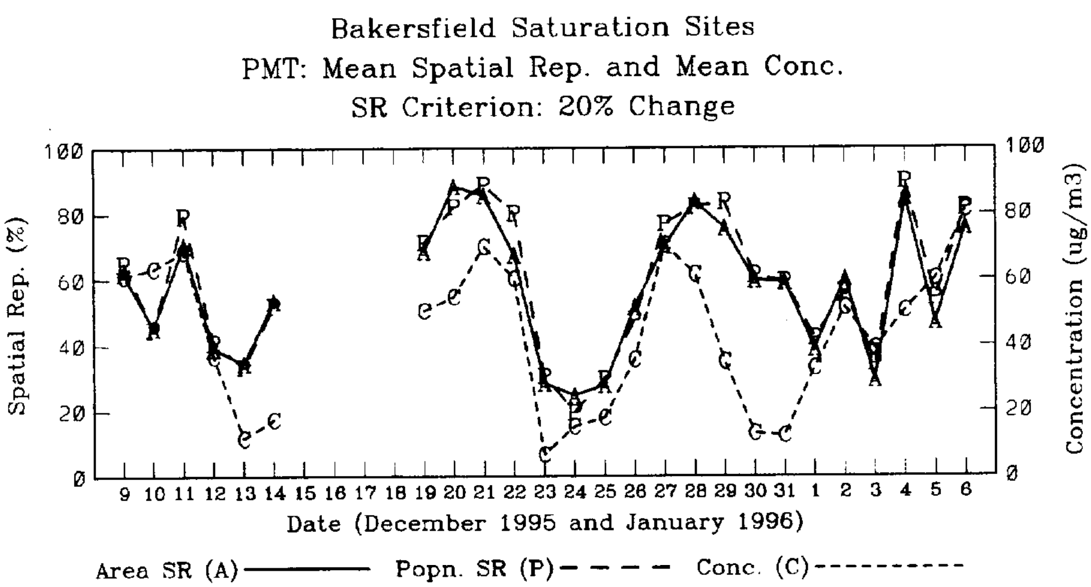


Figure 31. Mean spatial representativeness and concentration for Bakersfield sites, December 1995 and January 1996.

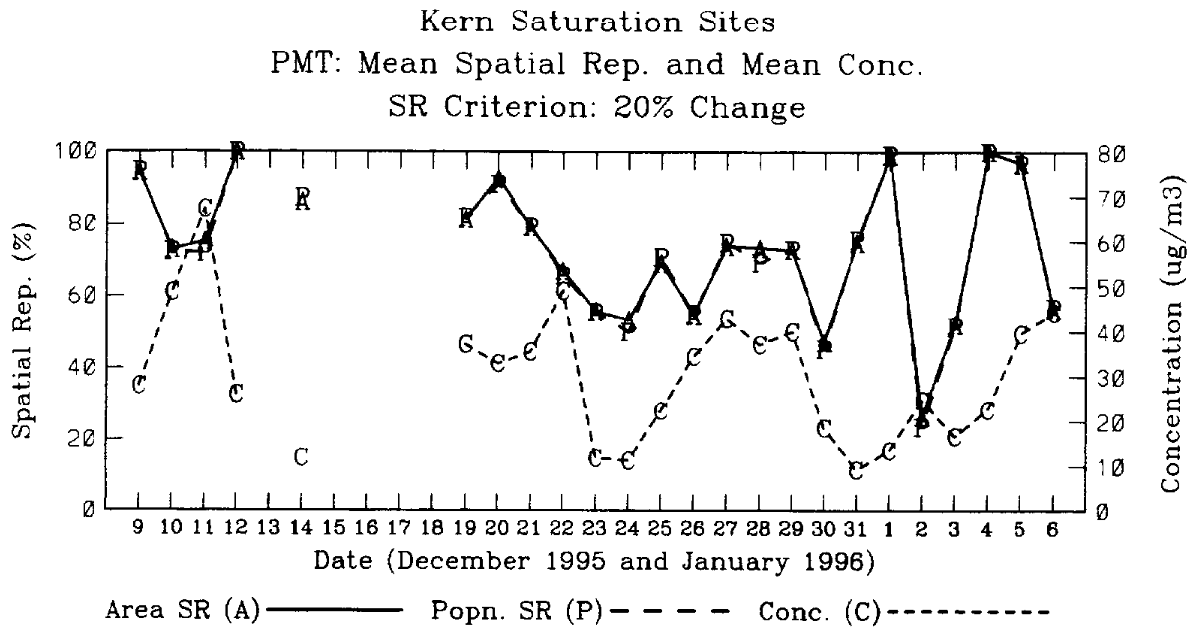


Figure 32. Mean spatial representativeness and PM_{10} concentration for Kern sites, December 1995 and January 1996.

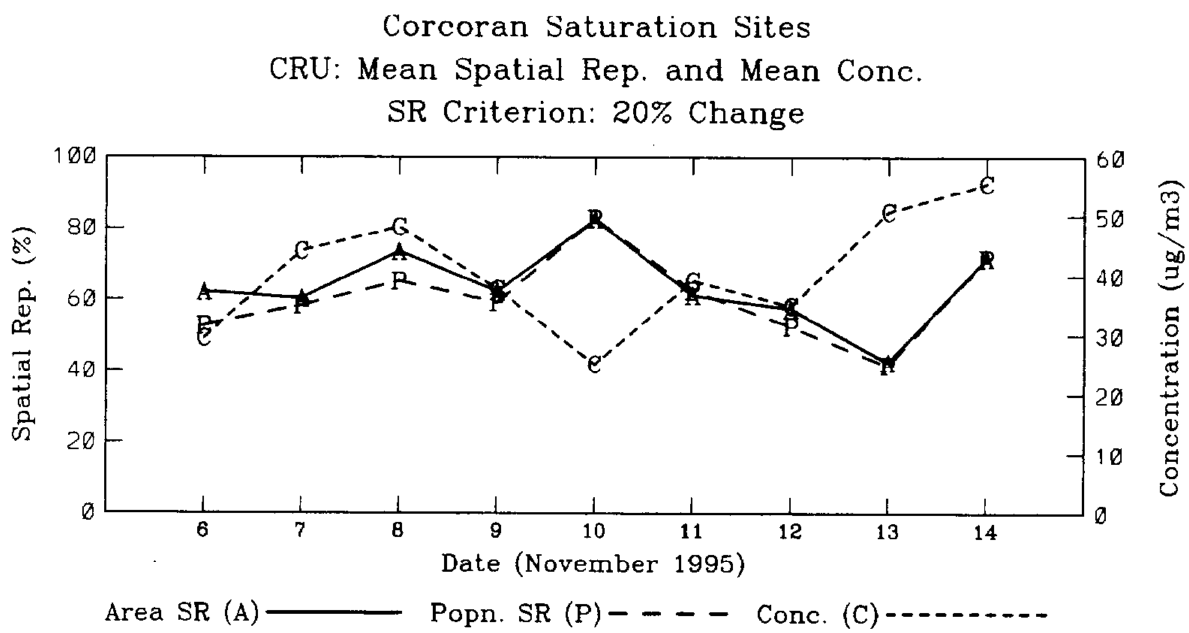


Figure 33. Mean spatial representativeness and concentration of crustal PM_{10} for Corcoran sites.

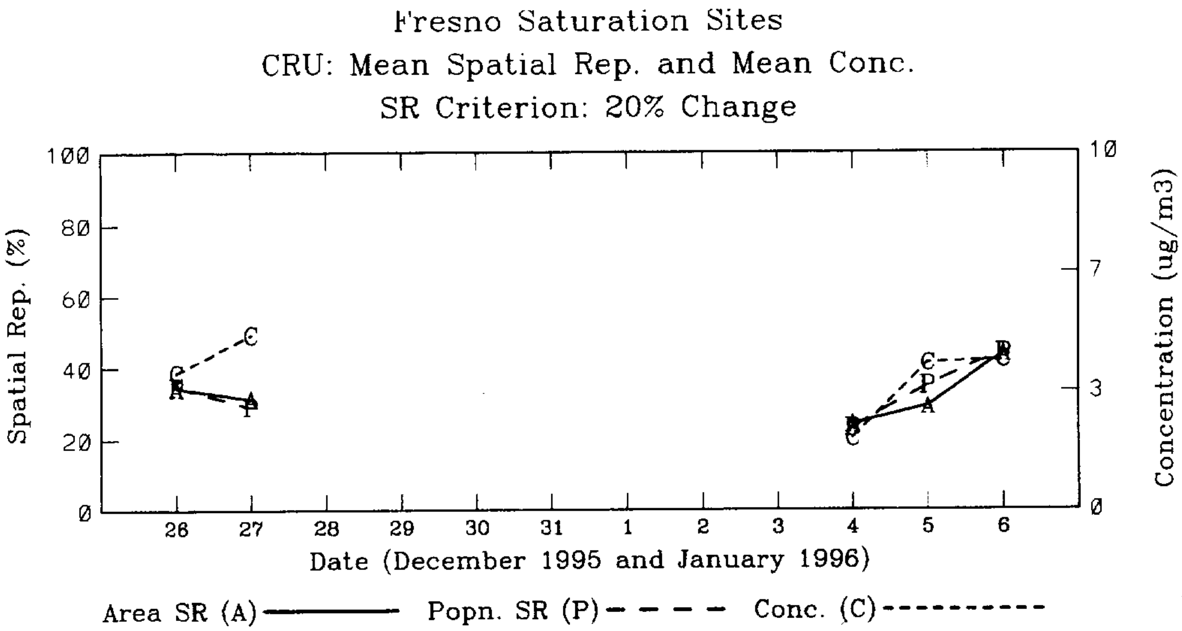


Figure 34. Mean spatial representativeness and concentration of crustal PM_{10} for Fresno sites.

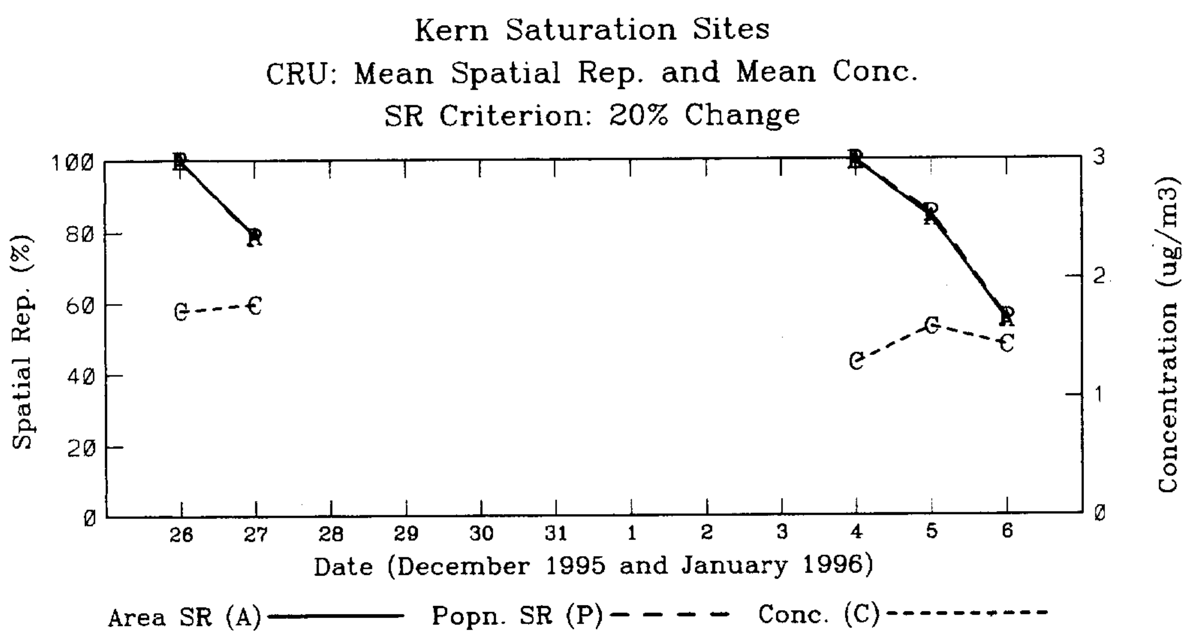


Figure 35. Mean spatial representativeness and concentration of crustal PM_{10} for Kern sites.

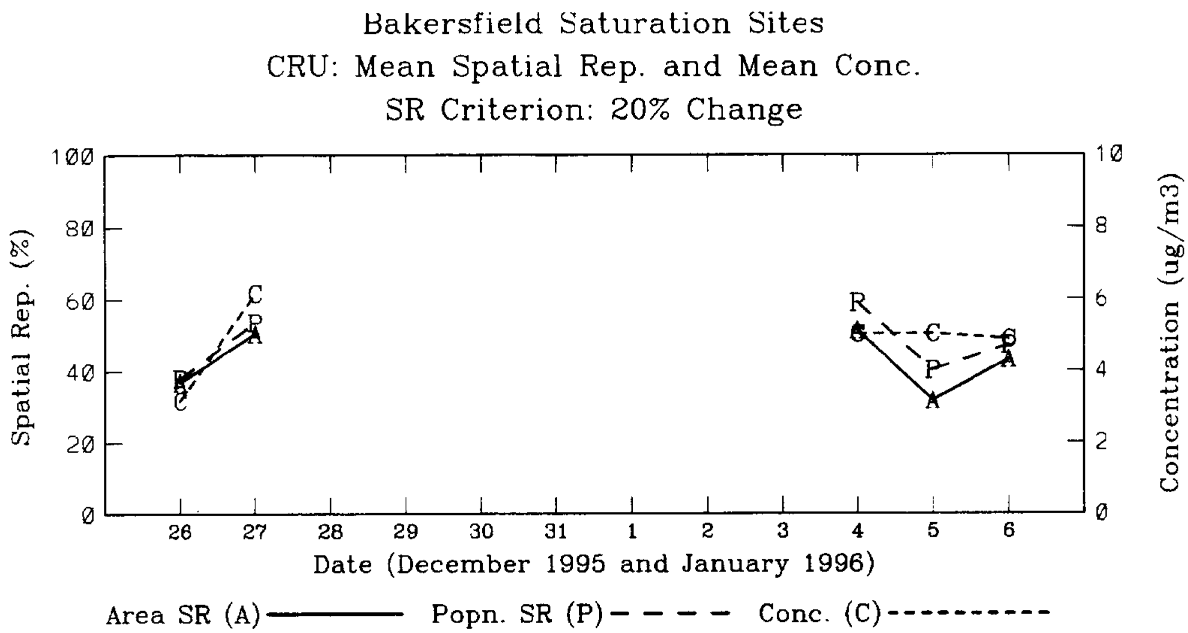


Figure 36. Mean spatial representativeness and concentration of crustal PM_{10} for Bakersfield sites.

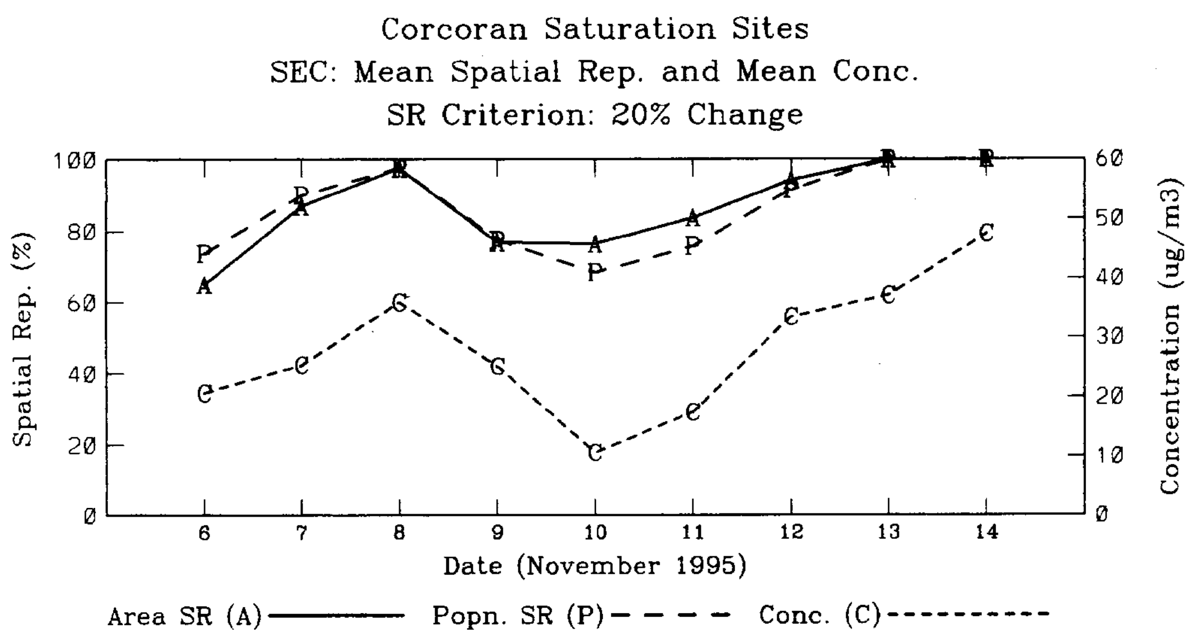


Figure 37. Mean spatial representativeness and concentration of secondary PM_{10} for Corcoran sites.

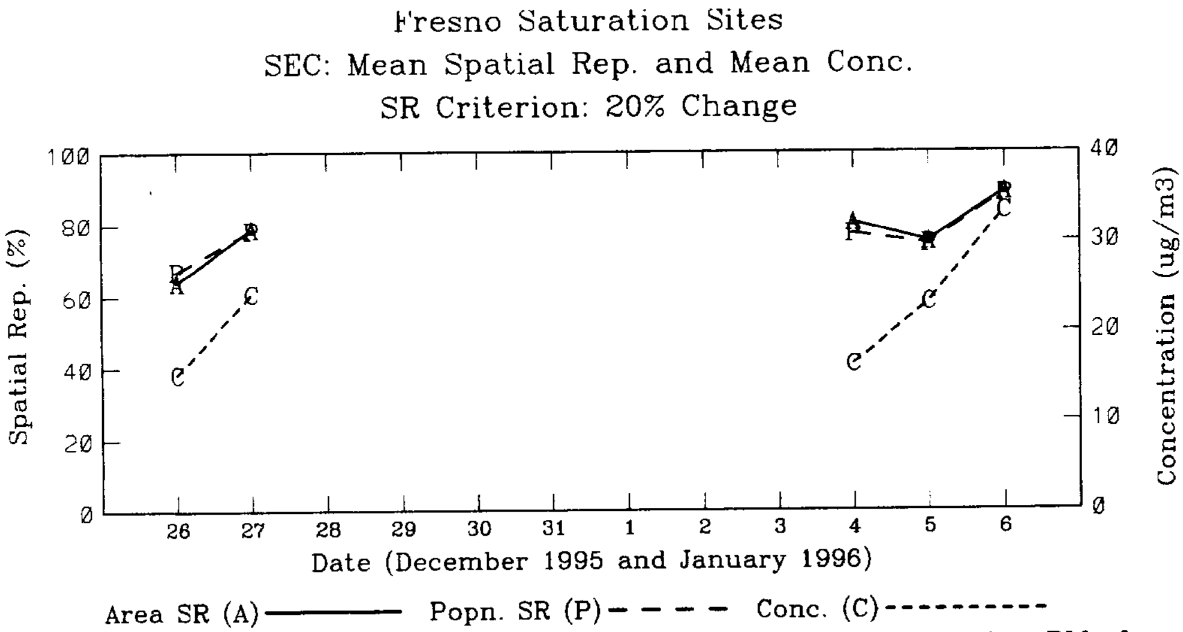


Figure 38. Mean spatial representativeness and concentration of secondary PM_{10} for Fresno sites.

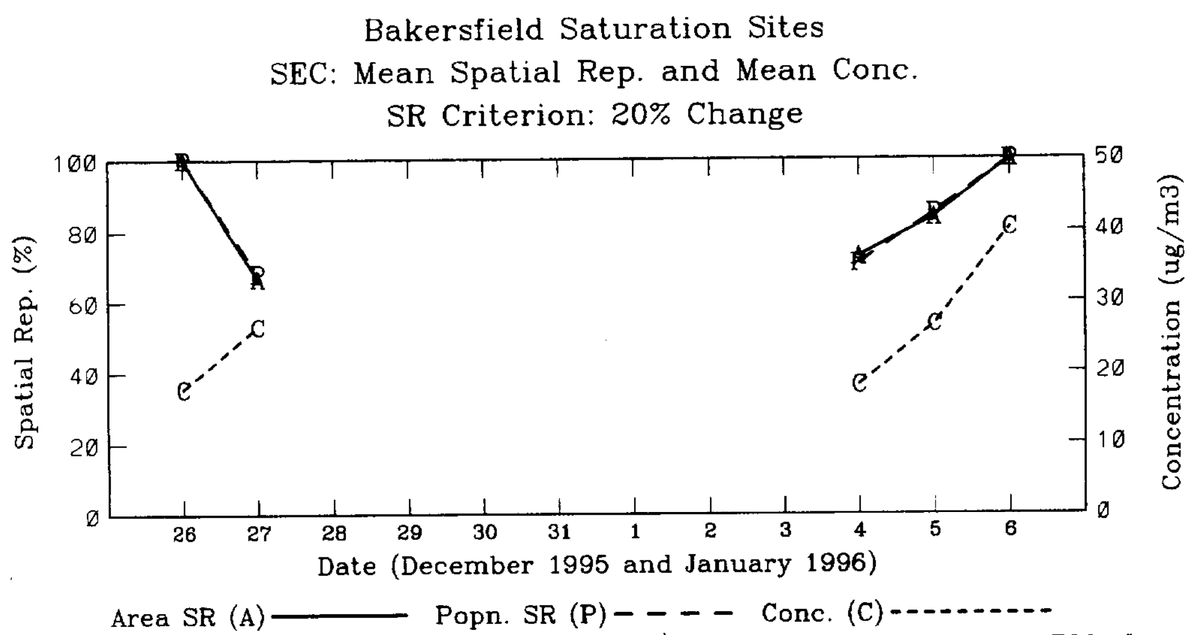


Figure 39. Mean spatial representativeness and concentration of secondary PM_{10} for Bakersfield sites.

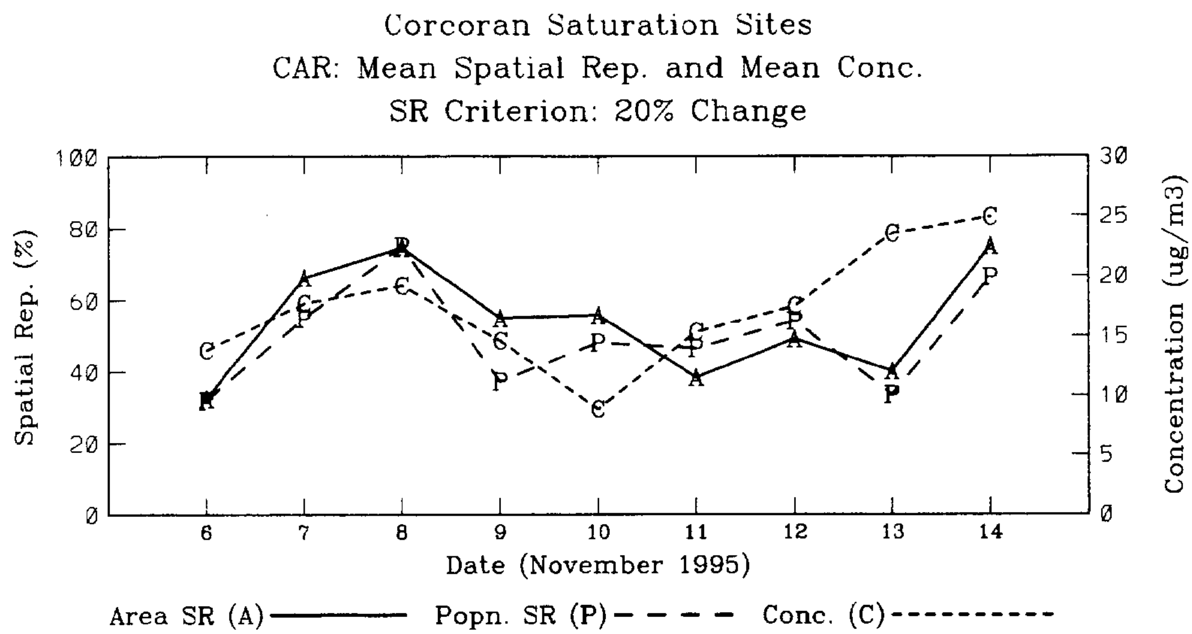


Figure 40. Mean spatial representativeness and concentration of carbon PM_{10} for Corcoran sites.

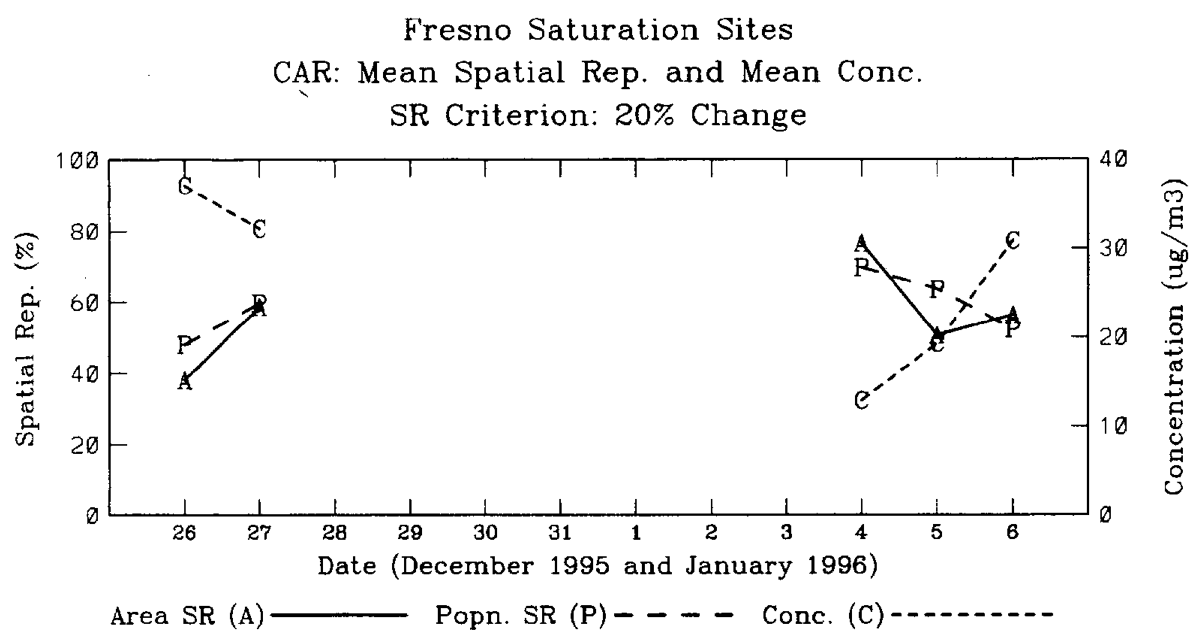


Figure 41. Mean spatial representativeness and concentration of carbon PM_{10} for Fresno sites.

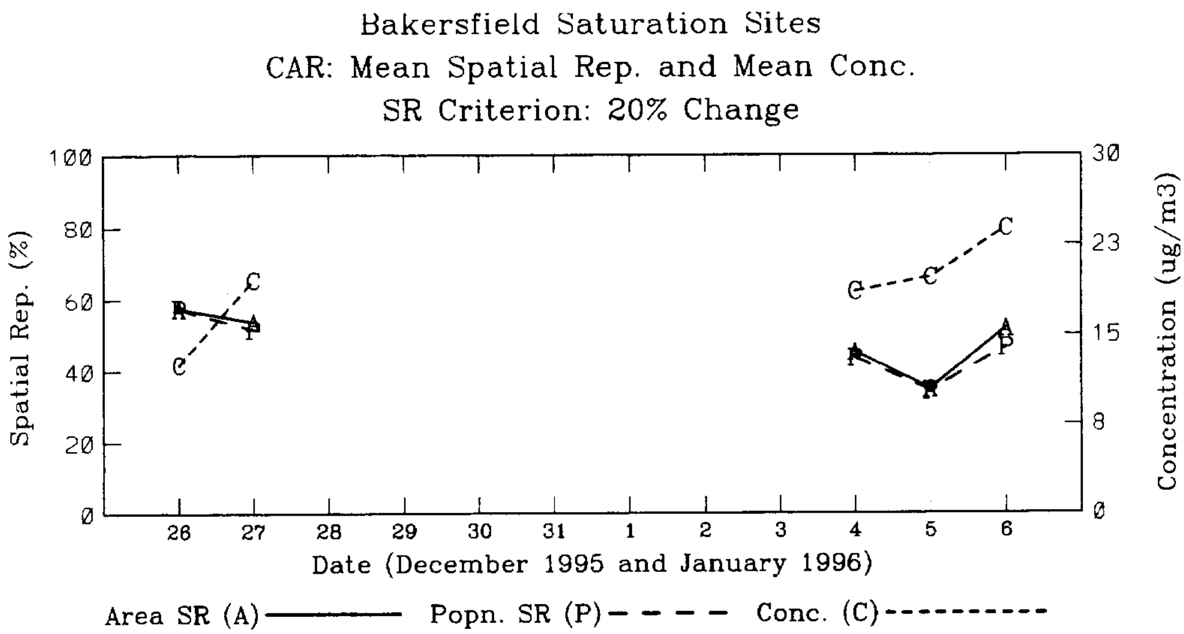


Figure 42. Mean spatial representativeness and concentration of carbon PM_{10} for Bakersfield sites.

Sensitivity Analyses

Effect of Alternative Percentage Criteria on Spatial Representativeness

Figure 43 shows mean spatial representativeness calculated for the Corcoran sites using percentage-change criteria ranging from 1% to 60%. Not surprisingly, a larger criterion results in more spatial representativeness. Less expected, however, is how similar the shapes of all the curves are. The curves for the higher and lower percentages become flat, as spatial representativeness asymptotes toward 100% and 0%. These curves do not tell us anything about the uncertainty of the measurements, but rather about the variability across the domain as defined by our measurements. A percentage-change criterion that produces a mid-range of spatial representativeness would be best for distinguishing between the spatial representativeness of different sites, although it might not be the one of choice for measuring the representativeness of a monitoring network.

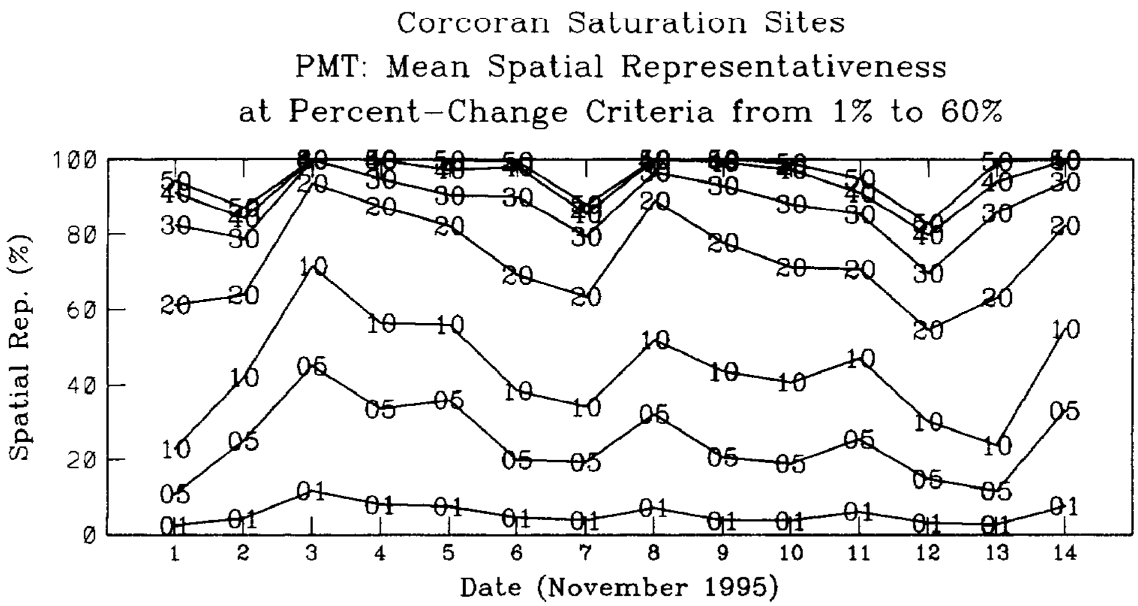


Figure 43. Mean spatial representativeness for Corcoran sites using percent-change criteria ranging from 1% to 60%.

The Use of Concentration as a Spatial Representativeness Criterion

Figures 44-47 show a comparison of mean SR for criteria of 20% and 10 μg/m³. For Corcoran, SR using concentration is similar to SR using percent. For the other three sites, however, it is quite different, probably because the concentrations are lower at those sites than at Corcoran. One notable ef t is an upward spike of SR whenever this is a downward spike in concentration. This effect and the high variability of SR based on concentration leads us to prefer the percentage-change criteria.

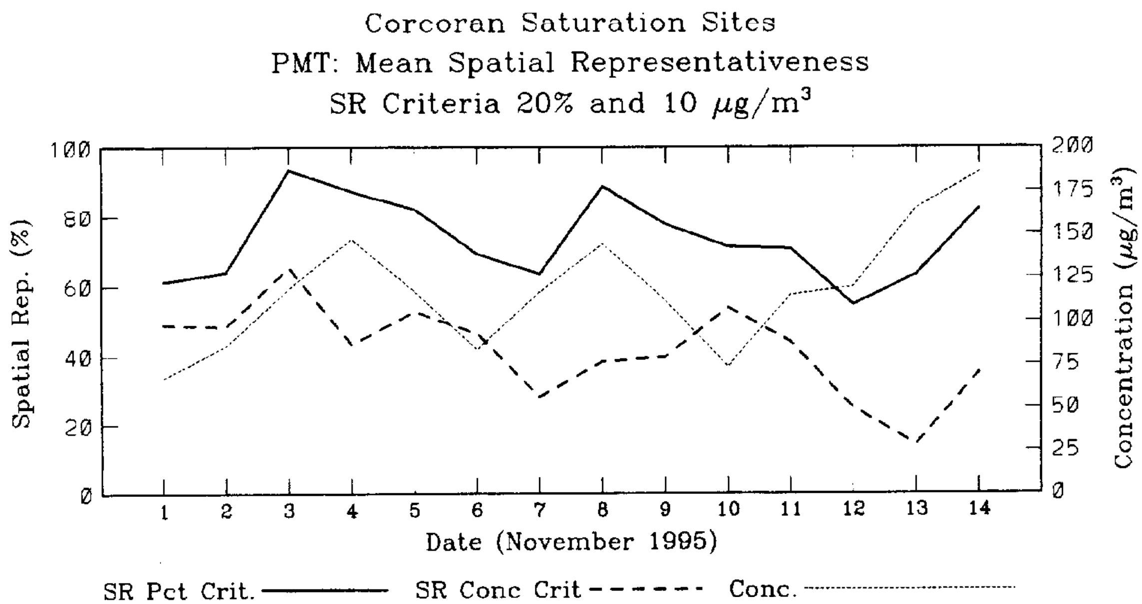


Figure 44. Spatial representativeness of Corcoran sites using percent-change and concentration-change criteria.

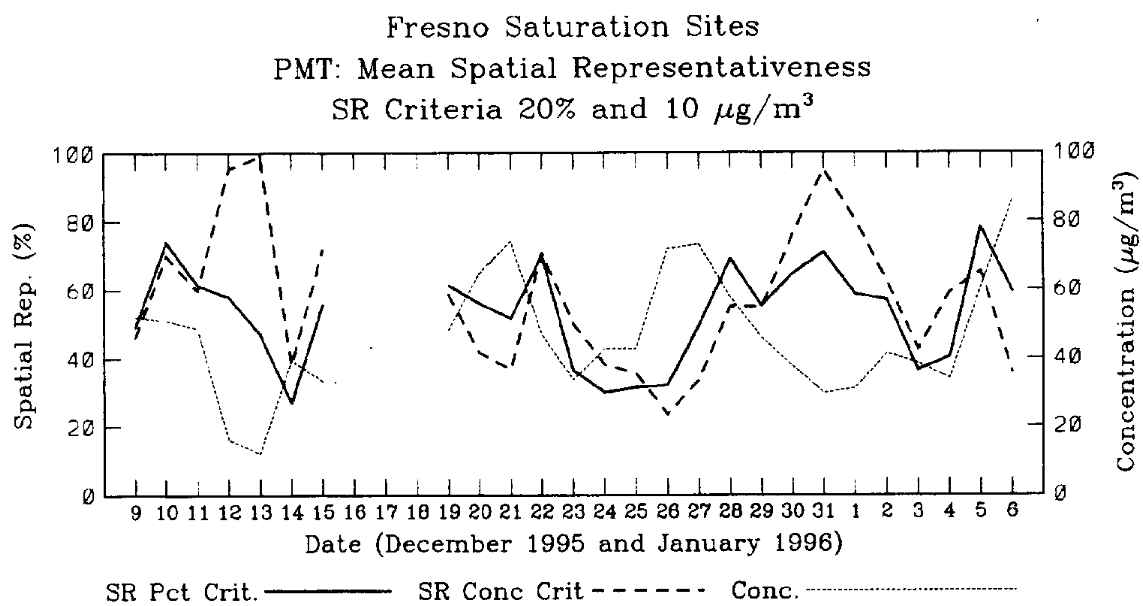


Figure 45. Spatial representativeness of Fresno sites using percent-change and concentration-change criteria.

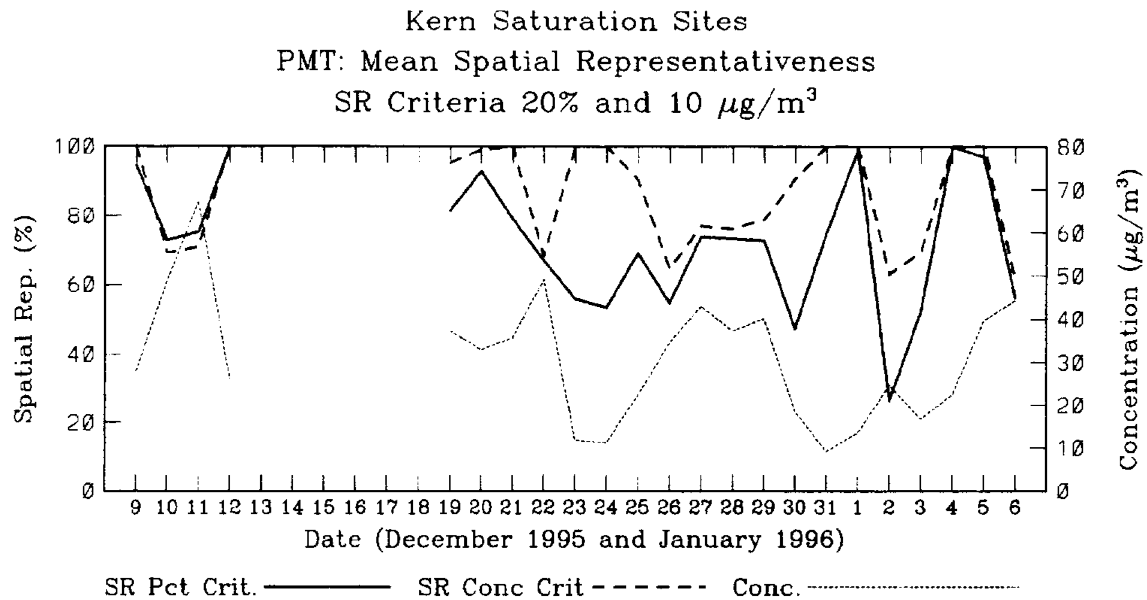


Figure 46. Spatial representativeness of Kern sites using percent-change and concentration-change criteria.

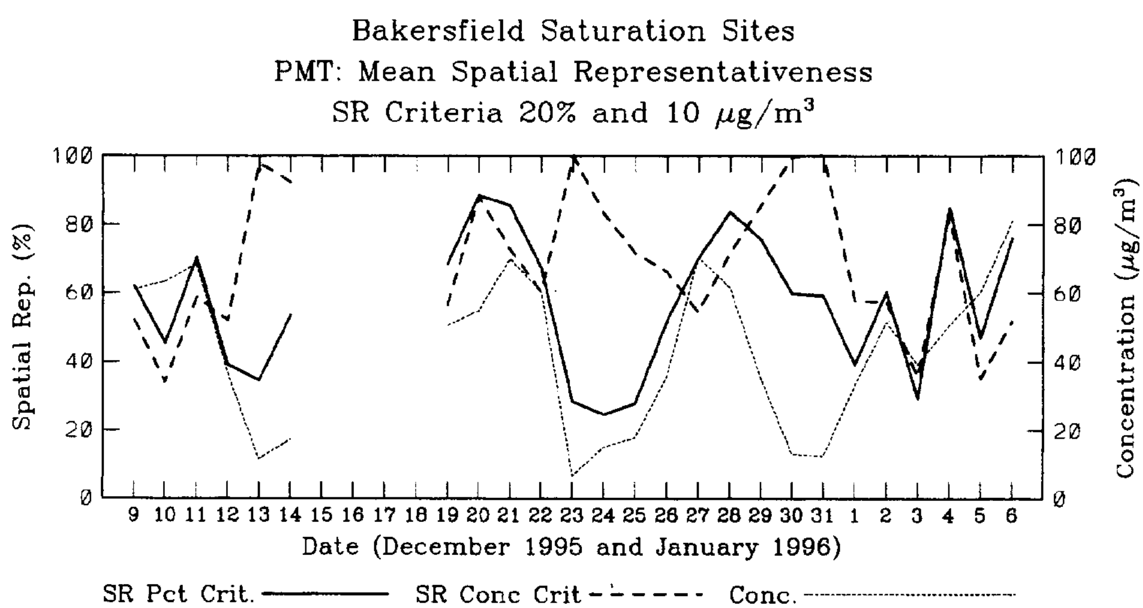


Figure 47. Spatial representativeness of Bakersfield sites using percent-change and concentration-change criteria.

Adequacy of the Monitoring Network

A network of monitoring sites is adequate when the sites represent, both spatially and population-wise, the concentration of pollutants throughout the domain. As discussed above, Figures 29-42 show that population representativeness (PR) and mean spatial representativeness (SR) track each other closely. The following discussion uses PR to determine how adequate the IMS95 network is, but either PR or SR would have been sufficient to determine adequacy, as they are closely correlated.

For each of the four networks (Corcoran, Fresno, Bakersfield, and Kern), we will evaluate what, if any, subset of the current network would be "adequate" to describe conditions in the entire domain. We define "adequacy" as a network subset that represents 90 percent or more of the average concentrations in the domain. The representation of maximum concentrations will be discussed separately, below.

Tables 27-30 show population spatial representativeness (20% criterion) for the Corcoran domain for PMT, CRU, SEC, and CAR, respectively. Tables 31-34 show the same results for Fresno, Tables 35-38 for Kern, and Tables 39-42 for Bakersfield. Each table shows the result for:

- the core site;
- the core site plus collocated site(s) (if any);
- the best, worst, and average of the core site plus all combinations of 1, 2 and 3 other sites; and
- the best, worst, and average of all combinations of 1, 2 and 3 sites (without requiring inclusion of the core site).

The results for Fresno carbon, crustal, and secondary species are limited because data for the core site (FEI) were missing on one of the five sample days and thus many combinations of the core with one or two other sites had only two or three days data (however, useful conclusions may still be drawn, as shown below).

Table 27. Population spatial representativeness of the Corcoran domain (20% criterion) for PMT for the core site and combinations of the core and saturation sites.

							Date (November 1995)														
	spp56	rank	st1	st2	st3	st4	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Avg
Single sites																					
Core site	pmt00	23	COV	--	--	--	-99	48	98	97	89	97	95	100	96	90	97	95	81	97	91
Worst	pmt00	1	C05	--	--	--	0	8	15	2	1	8	18	11	1	80	10	6	1	1	12
Best	pmt00	23	COV	--	--	--	-99	48	98	97	89	97	95	100	96	90	97	95	81	97	91
Average	pmt00	Avg	Avg	--	--	--	52	71	93	85	78	69	63	85	74	72	72	57	61	82	73
N	pmt00	N	N	--	--	--	21	22	22	23	23	22	22	23	23	23	23	22	23	22	23
Core plus one saturation site																					
Colloc	pmt21	12	COV	C04	--	--	-99	86	99	97	95	97	96	100	98	94	98	96	92	99	96
Worst	pmt21	1	COV	C02	--	--	-99	50	98	97	89	97	97	100	96	90	99	97	81	97	91
Best	pmt21	22	COV	C16	--	--	-99	97	100	100	100	99	97	100	99	100	98	96	100	100	99
Average	pmt21	Avg	Avg	--	--	--	-99	82	99	98	94	98	97	100	98	97	98	96	89	98	96
N	pmt21	N	N	--	--	--	0	21	21	22	22	21	21	22	22	22	22	21	22	21	22
Core plus two saturation sites																					
Worst	pmt22	1	COV	C02	C07	--	-99	50	99	97	89	99	99	100	96	90	99	98	81	97	92
Best	pmt22	231	COV	C06	C12	--	-99	98	100	100	100	100	-99	100	100	100	98	-99	100	99	99
Average	pmt22	Avg	Avg	--	--	--	-99	93	100	99	96	99	98	100	99	99	99	97	94	99	98
N	pmt22	N	N	--	--	--	0	210	210	231	231	210	210	231	231	231	231	210	231	210	231
Core plus three saturation sites																					
Worst	pmt23	1	COV	C01	C02	C07	-99	60	99	99	98	99	99	100	96	92	99	98	83	97	94
Best	pmt23	1540	COV	C05	C06	C09	-99	99	100	100	100	-99	-99	100	100	100	99	-99	100	100	100
Average	pmt23	Avg	Avg	--	--	--	-99	97	100	99	98	99	99	100	99	100	99	98	96	99	99
N	pmt23	N	N	--	--	--	0	1330	1330	1540	1540	1330	1330	1540	1540	1540	1540	1330	1540	1330	1540
Combinations of two sites (core and saturation)																					
Worst	pmt32	1	C02	C05	--	--	69	57	72	100	73	100	19	91	81	92	12	9	25	45	60
Best	pmt32	253	C06	C09	--	--	95	98	100	100	99	-99	-99	100	100	99	99	-99	99	99	99
Average	pmt32	Avg	Avg	--	--	--	72	91	99	97	94	91	86	97	92	93	92	82	84	96	91
N	pmt32	N	N	--	--	--	210	231	231	253	253	231	231	253	253	253	253	231	253	231	253
Combinations of three sites (core and saturation)																					
Worst	pmt33	1	C02	C05	C20	--	70	99	100	100	73	100	29	91	100	100	12	92	41	98	79
Best	pmt33	1771	C14	C16	C22	--	-99	-99	-99	100	100	100	100	100	100	100	99	99	100	-99	100
Average	pmt33	Avg	Avg	--	--	--	81	96	100	99	97	97	95	99	97	98	98	92	93	99	96
N	pmt33	N	N	--	--	--	1330	1540	1540	1771	1771	1540	1540	1771	1771	1771	1771	1540	1771	1540	1771

Table 28. Population spatial representativeness of the Corcoran domain (20% criterion) for CRU for the core site and combinations of the core and saturation sites.

	spp56	rank	st1	st2	st3	st4	6	7	8	9	10	11	12	13	14	Avg
							Date (November 1995)									
Single sites																
Coresite	cru00	14	COV	--	--	--	28	26	32	37	89	94	54	25	2	43
Worst	cru00	13	C05	--	--	--	10	5	13	3	82	5	59	2	8	21
Best	cru00	23	C06	--	--	--	69	-99	72	86	98	95	-99	68	95	83
Average	cru00	Avg	Avg	--	--	--	50	55	62	57	83	65	53	40	65	60
N	cru00	N	N	--	--	--	10	10	11	11	11	11	10	11	11	11
Core plus one saturation site																
Worst	cru21	13	COV	C05	--	--	38	32	45	40	100	97	99	26	10	54
Best	cru21	22	COV	C06	--	--	97	-99	100	98	98	95	-99	93	95	97
Average	cru21	Avg	Avg	--	--	--	72	72	76	74	97	95	75	54	72	77
N	cru21	N	N	--	--	--	9	9	10	10	10	10	9	10	10	10
Core plus two saturation sites																
Worst	cru22	187	COV	C05	C19	--	38	95	61	40	100	98	99	26	100	73
Best	cru22	231	COV	C05	C13	--	100	100	100	100	100	100	99	94	100	99
Average	cru22	Avg	Avg	--	--	--	90	90	92	90	99	97	87	74	94	91
N	cru22	N	N	--	--	--	36	36	45	45	45	45	36	45	45	45
Core plus three saturation sites																
Worst	cru23	1421	COV	C03	C09	C19	-99	99	90	37	100	96	97	43	96	82
Best	cru23	1540	COV	C05	C11	C13	100	100	100	100	100	100	99	99	100	100
Average	cru23	Avg	Avg	--	--	--	97	96	97	97	100	97	93	86	99	96
N	cru23	N	N	--	--	--	84	84	120	120	120	120	84	120	120	120
Combinations of two sites (core and saturation)																
Worst	cru32	199	COV	C05	--	--	38	32	45	40	100	97	99	26	10	54
Best	cru32	253	C09	C15	--	--	-99	97	100	98	96	98	97	99	100	98
Average	cru32	Avg	Avg	--	--	--	76	81	86	83	98	88	78	65	90	84
N	cru32	N	N	--	--	--	45	45	55	55	55	55	45	55	55	55
Combinations of three sites (core and saturation)																
Worst	cru33	1607	COV	C05	C19	--	38	95	61	40	100	98	99	26	100	73
Best	cru33	1771	C05	C06	C09	--	-99	-99	100	100	100	98	-99	99	100	100
Average	cru33	Avg	Avg	--	--	--	89	93	95	94	100	96	89	81	97	93
N	cru33	N	N	--	--	--	120	120	165	165	165	165	120	165	165	165

Table 29. Population spatial representativeness of the Corcoran domain (20% criterion) for SEC for the core site and combinations of the core and saturation sites.

							Date (November 1995)								
	spp56	rank	st1	st2	st3	st4	6	7	8	9	10	11	12	13	14	Avg
Single sites																
Coresite	sec00	17	COV	--	--	--	97	97	99	98	45	18	100	100	100	84
Worst	sec00	13	C20	--	--	--	2	-99	100	12	14	85	86	100	100	62
Best	sec00	23	C08	--	--	--	97	-99	100	99	93	72	100	100	100	95
Average	sec00	Avg	Avg	--	--	--	76	92	98	79	66	70	93	100	100	86
N	sec00	N	N	--	--	--	9	5	11	10	11	11	8	11	11	11
Core plus one saturation site																
Worst	sec21	13	COV	C03	--	--	97	97	99	98	69	55	100	100	100	91
Best	sec21	22	COV	C13	--	--	99	100	100	99	100	100	-99	100	100	100
Average	sec21	Avg	Avg	--	--	--	97	99	100	99	78	78	100	100	100	94
N	sec21	N	N	--	--	--	8	4	10	9	10	10	7	10	10	10
Core plus two saturation sites																
Worst	sec22	187	COV	C03	C09	--	-99	-99	100	98	73	77	-99	100	100	91
Best	sec22	231	COV	C06	C19	--	-99	-99	100	-99	100	100	-99	100	100	100
Average	sec22	Avg	Avg	--	--	--	98	100	100	100	89	90	100	100	100	97
N	sec22	N	N	--	--	--	28	6	45	36	45	45	21	45	45	45
Core plus three saturation sites																
Worst	sec23	1421	COV	C03	C09	C20	-99	-99	100	100	73	85	-99	100	100	93
Best	sec23	1540	COV	C05	C06	C13	-99	-99	100	100	100	100	-99	100	100	100
Average	sec23	Avg	Avg	--	--	--	98	100	100	100	93	93	100	100	100	98
N	sec23	N	N	--	--	--	56	4	120	84	120	120	35	120	120	120
Combinations of two sites (core and saturation)																
Worst	sec32	199	C06	C20	--	--	-99	-99	100	24	77	90	-99	100	100	82
Best	sec32	253	C06	C19	--	--	-99	-99	100	-99	100	100	-99	100	100	100
Average	sec32	Avg	Avg	--	--	--	94	99	100	97	85	87	99	100	100	95
N	sec32	N	N	--	--	--	36	10	55	45	55	55	28	55	55	55
Combinations of three sites (core and saturation)																
Worst	sec33	1607	COV	C03	C09	--	99	-99	100	98	73	77	-99	100	100	91
Best	sec33	1771	C06	C08	C19	--	-99	-99	100	-99	100	100	-99	100	100	100
Average	sec33	Avg	Avg	--	--	--	97	100	100	100	92	92	100	100	100	97
N	sec33	N	N	--	--	--	84	10	165	120	165	165	56	165	165	165

Table 30. Population spatial representativeness of the Corcoran domain (20% criterion) for CAR for the core site and combinations of the core and saturation sites.

							Date (November 1995)									
	spp56	rank	st1	st2	st3	st4	6	7	8	9	10	11	12	13	14	Avg
Single sites																
Core site	car00	23	COV	--	--	--	38	69	21	67	95	93	94	73	97	72
Worst	car00	13	C05	--	--	--	1	3	67	1	3	48	39	1	1	18
Best	car00	23	COV	--	--	--	38	69	21	67	95	93	94	73	97	72
Average	car00	Avg	Avg	--	--	--	33	56	70	40	52	51	58	37	69	52
N	car00	N	N	--	--	--	10	10	11	11	11	11	10	11	11	11
Core plus one saturation site																
Worst	car21	13	COV	C03	--	--	38	93	21	80	95	96	96	74	97	77
Best	car21	22	COV	C09	--	--	-99	95	100	72	96	93	97	74	98	91
Average	car21	Avg	Avg	--	--	--	51	88	82	74	97	95	96	76	98	84
N	car21	N	N	--	--	--	9	9	10	10	10	10	9	10	10	10
Core plus two saturation sites																
Worst	car22	187	COV	C03	C05	--	39	96	67	81	99	96	98	75	99	83
Best	car22	231	COV	C06	C20	--	96	-99	100	77	100	94	-99	98	98	95
Average	car22	Avg	Avg	--	--	--	62	95	97	79	98	96	97	79	98	90
N	car22	N	N	--	--	--	36	36	45	45	45	45	36	45	45	45
Core plus three saturation sites																
Worst	car23	1421	COV	C05	C13	C15	42	82	100	78	100	98	97	75	99	86
Best	car23	1540	COV	C06	C19	C20	97	-99	100	93	100	94	-99	98	98	97
Average	car23	Avg	Avg	--	--	--	72	97	100	82	98	97	98	82	98	92
N	car23	N	N	--	--	--	84	84	120	120	120	120	84	120	120	120
Combinations of two sites (core and saturation)																
Worst	car32	199	C03	C05	--	--	34	79	67	21	3	51	98	3	2	40
Best	car32	253	COV	C09	--	--	-99	95	100	72	96	93	97	74	98	91
Average	car32	Avg	Avg	--	--	--	53	80	93	61	78	77	84	58	89	75
N	car32	N	N	--	--	--	45	45	55	55	55	55	45	55	55	55
Combinations of three sites (core and saturation)																
Worst	car33	1607	C03	C05	C20	--	81	80	100	37	47	51	99	3	44	60
Best	car33	1771	COV	C06	C20	--	96	-99	100	77	100	94	-99	98	98	95
Average	car33	Avg	Avg	--	--	--	66	89	99	73	90	90	94	70	94	85
N	car33	N	N	--	--	--	120	120	165	165	165	165	120	165	165	165

Table 31. Population spatial representativeness of the Fresno domain (20% criterion) for PMT for the core site and combinations of the core and saturation sites.

							Date (December 1995 and January 1996)																										
	spp56	rank	st1	st2	st3	st4	9	10	11	12	13	14	15	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	Avg
Single sites																																	
Core	pmt00	15	FEI	--	--	--	64	63	61	10	29	83	-99	89	31	14	79	22	27	55	4	24	81	60	75	77	87	90	37	44	98	94	56
Wrst	pmt00	1	F36	--	--	--	3	5	14	4	42	8	3	15	5	7	88	0	0	4	0	71	88	9	95	-99	5	1	43	1	49	2	22
Best	pmt00	26	F43	--	--	--	89	95	78	83	57	78	74	95	85	72	82	55	67	77	-99	74	3	78	96	96	88	96	33	0	11	97	70
Avg	pmt00	Avg	Avg	--	--	--	51	74	51	55	45	41	59	67	52	49	66	32	31	39	36	44	68	56	65	68	63	69	31	38	76	65	54
N	pmt00	N	N	--	--	--	21	25	26	26	23	26	24	26	25	26	25	25	25	26	22	25	26	25	26	23	25	26	26	25	23	22	26
Core plus one saturation site																																	
Col	pmt21	4	FEI	F21	--	--	67	84	64	78	29	91	91	67	34	89	25	29	59	36	31	87	60	85	87	99	90	37	89	99	94	68	
Wrst	pmt21	1	FEI	F20	--	--	-99	73	86	10	29	87	89	31	52	84	22	31	62	24	24	0	86	64	79	77	87	90	37	95	99	94	63
Best	pmt21	25	FEI	F43	--	--	90	95	93	84	57	90	95	86	86	95	77	67	78	-99	95	0	84	78	96	96	88	97	37	44	99	97	84
Avg	pmt21	Avg	Avg	--	--	--	83	91	73	61	61	88	94	69	58	86	48	48	69	40	58	0	91	78	89	90	94	95	52	67	99	97	75
N	pmt21	N	N	--	--	--	20	24	25	25	22	25	25	24	25	24	24	24	25	21	24	0	25	24	25	22	24	25	25	24	22	21	25
Core plus two saturation sites																																	
Wrst	pmt22	1	FEI	F20	F21	--	-99	84	89	78	29	94	91	67	52	89	25	33	62	36	31	0	87	64	85	87	99	90	37	99	100	94	71
Best	pmt22	300	FEI	F19	F25	--	96	99	85	93	-99	92	99	100	92	96	99	-99	95	86	98	0	98	79	96	98	99	99	85	100	100	-99	95
Avg	pmt22	Avg	Avg	--	--	--	92	97	81	82	78	91	97	86	79	90	65	63	79	63	77	0	95	88	94	95	97	97	63	82	99	98	85
N	pmt22	N	N	--	--	--	190	276	300	300	231	300	300	276	300	276	276	276	300	210	276	0	300	276	300	231	276	300	300	276	231	210	300
Core plus three saturation sites																																	
Wrst	pmt23	1	FEI	F20	F21	F27	-99	94	89	99	-99	94	91	67	52	92	33	50	62	36	31	0	96	64	85	89	99	90	78	99	-99	96	77
Best	pmt23	2300	FEI	F19	F25	F26	97	99	97	99	-99	94	99	100	93	96	99	-99	99	-99	100	0	100	95	100	-99	99	100	93	100	100	-99	98
Avg	pmt23	Avg	Avg	--	--	--	96	99	86	91	88	93	98	94	88	92	77	74	85	78	87	0	98	92	97	98	98	98	71	90	100	99	90
N	pmt23	N	N	--	--	--	1140	2024	2300	2300	1540	2300	2300	2024	2300	2024	2024	2024	2300	1330	2024	0	2300	2024	2300	1540	2024	2300	2300	2024	1540	1330	2300
Combinations of two sites (core and saturation)																																	
Wrst	pmt32	1	F34	F36	--	--	3	32	14	89	79	8	4	15	26	8	88	2	1	4	0	71	93	25	96	-99	12	1	48	1	78	2	32
Best	pmt32	325	F19	F43	--	--	95	99	93	84	-99	80	98	99	96	92	95	92	99	94	-99	94	87	79	96	96	99	98	33	72	100	-99	90
Avg	pmt32	Avg	Avg	--	--	--	76	93	73	79	70	65	83	89	78	73	85	55	52	63	59	69	89	79	88	90	87	90	51	63	94	89	76
N	pmt32	N	N	--	--	--	210	300	325	325	253	325	276	325	300	325	300	300	300	325	231	300	325	300	325	253	300	325	325	300	253	231	325
Combinations of three sites (core and saturation)																																	
Wrst	pmt33	1	F34	F35	F36	--	3	54	39	89	97	9	25	25	-99	75	88	19	16	4	1	94	99	97	96	-99	14	67	94	5	99	4	51
Best	pmt33	2600	F23	F32	F33	--	-99	95	89	98	-99	92	96	97	99	92	94	-99	92	98	99	97	99	96	100	-99	-99	99	88	94	-99	99	96
Avg	pmt33	Avg	Avg	--	--	--	88	98	83	89	83	79	92	96	90	85	91	70	68	77	75	82	96	89	95	96	95	96	64	78	99	96	86
N	pmt33	N	N	--	--	--	1330	2300	2600	2600	1771	2600	2024	2600	2300	2600	2300	2300	2300	2600	1540	2300	2600	2300	2600	1771	2300	2600	2600	2300	1771	1540	2600

Table 32. Population spatial representativeness of the Fresno domain (20% criterion) for CRU for the core site and combinations of the core and saturation sites.

							Date (December 1995 and January 1996)					
	spp56	rank	st1	st2	st3	st4	26	27	4	5	6	Avg
Single sites												
Core	cru00	13	FEI	--	--	--	-99	56	13	39	48	39
Worst	cru00	1	F36	--	--	--	0	7	0	0	1	2
Best	cru00	26	F22	--	--	--	81	47	64	75	86	71
Avg	cru00	Avg	Avg	--	--	--	35	30	23	35	45	34
N	cru00	N	N	--	--	--	21	25	25	23	23	26
Core plus one saturation site												
Colloc	cru21	17	FEI	F21	--	--		87	13	41	95	59
Worst	cru21	1	FEI	F29	--	--	-99	61	13	41	-99	38
Best	cru21	25	FEI	F40	--	--	-99	91	-99	90	-99	91
Avg	cru21	Avg	Avg	--	--	--	-99	71	30	56	71	57
N	cru21	N	N	--	--	--	0	24	24	22	22	25
Core plus two saturation sites												
Worst	cru22	1	FEI	F29	F42	--	-99	-99	18	48	-99	33
Best	cru22	300	FEI	F27	F32	--	-99	93	94	-99	99	95
Avg	cru22	Avg	Avg	--	--	--	-99	81	43	68	84	69
N	cru22	N	N	--	--	--	0	276	276	231	231	300
Core plus three saturation sites												
Worst	cru23	4	FEI	F29	F36	F42	-99	-99	18	48	-99	33
Best	cru23	2300	FEI	F25	F27	F40	-99	98	-99	-99	-99	98
Avg	cru23	Avg	Avg	--	--	--	-99	87	53	77	91	77
N	cru23	N	N	--	--	--	0	2024	2024	1540	1540	2297
Combinations of two sites (core and saturation)												
Worst	cru32	1	F18	F36	--	--	0	7	0	2	3	3
Best	cru32	325	F24	F40	--	--	98	90	-99	-99	-99	94
Avg	cru32	Avg	Avg	--	--	--	58	52	39	57	70	55
N	cru32	N	N	--	--	--	210	300	300	253	253	325
Combinations of three sites (core and saturation)												
Worst	cru33	1	F18	F36	F39	--	-99	8	16	8	5	9
Best	cru33	2600	F24	F40	F42	--	99	-99	-99	-99	-99	99
Avg	cru33	Avg	Avg	--	--	--	73	67	50	71	83	68
N	cru33	N	N	--	--	--	1330	2300	2300	1771	1771	2600

Table 33. Population spatial representativeness of the Fresno domain (20% criterion) for SEC for the core site and combinations of the core and saturation sites.

							Date (December 1995 and January 1996)					
	spp56	rank	st1	st2	st3	st4	26	27	4	5	6	Avg
Single sites												
Core	sec00	23	FEI	--	--	--	-99	99	80	92	95	91
Worst	sec00	13	F35	--	--	--	12	21	93	17	100	49
Best	sec00	26	F40	--	--	--	98	99	-99	95	-99	97
Avg	sec00	Avg	Avg	--	--	--	67	80	77	76	89	79
N	sec00	N	N	--	--	--	11	14	13	10	10	14
Core plus one saturation site												
Worst	sec21	13	FEI	F39	--	--	-99	100	80	92	96	92
Best	sec21	25	FEI	F35	--	--	-99	100	100	100	100	100
Avg	sec21	Avg	Avg	--	--	--	-99	99	94	96	98	97
N	sec21	N	N	--	--	--	0	13	12	9	9	13
Core plus two saturation sites												
Worst	sec22	223	FEI	F33	F39	--	-99	100	86	-99	100	95
Best	sec22	300	FEI	F24	F35	--	-99	100	100	-99	100	100
Avg	sec22	Avg	Avg	--	--	--	-99	100	98	98	99	99
N	sec22	N	N	--	--	--	0	78	66	36	36	78
Core plus three saturation sites												
Worst	sec23	2015	FEI	F28	F31	F39	-99	100	91	100	-99	97
Best	sec23	2300	FEI	F30	F35	F40	-99	100	-99	100	-99	100
Avg	sec23	Avg	Avg	--	--	--	-99	100	99	99	100	99
N	sec23	N	N	--	--	--	0	286	220	84	84	286
Combinations of two sites (core and saturation)												
Worst	sec32	235	F30	F35	--	--	24	23	95	100	100	68
Best	sec32	325	F35	F40	--	--	100	99	-99	100	-99	100
Avg	sec32	Avg	Avg	--	--	--	91	96	95	95	99	96
N	sec32	N	N	--	--	--	55	91	78	45	45	91
Combinations of three sites (core and saturation)												
Worst	sec33	2237	F28	F30	F35	--	41	64	99	100	100	81
Best	sec33	2600	F27	F30	F40	--	100	100	-99	-99	-99	100
Avg	sec33	Avg	Avg	--	--	--	98	99	98	99	100	99
N	sec33	N	N	--	--	--	165	364	286	120	120	364

Table 34. Population spatial representativeness of the Fresno domain (20% criterion) for CAR for the core site and combinations of the core and saturation sites.

	spp56	rank	st1	st2	st3	st4	26	27	4	5	6	Avg
							Date (December 1995 and January 1996)					
Single sites												
Core	car00	25	FEI	--	--	--	-99	89	85	91	85	88
Worst	car00	13	F40	--	--	--	0	1	-99	8	-99	3
Best	car00	26	F29	--	--	--	86	97	92	89	-99	91
Avg	car00	Avg	Avg	--	--	--	48	62	71	66	55	60
N	car00	N	N	--	--	--	11	14	13	10	11	14
Core plus one saturation site												
Worst	car21	13	FEI	F33	--	--	-99	90	87	-99	92	90
Best	car21	25	FEI	F39	--	--	-99	100	95	98	89	96
Avg	car21	Avg	Avg	--	--	--	-99	95	91	95	90	93
N	car21	N	N	--	--	--	0	13	12	9	10	13
Core plus two saturation sites												
Worst	car22	223	FEI	F38	F40	--	-99	90	-99	-99	-99	90
Best	car22	300	FEI	F27	F40	--	-99	100	-99	-99	-99	100
Avg	car22	Avg	Avg	--	--	--	-99	98	94	97	94	96
N	car22	N	N	--	--	--	0	78	66	36	45	78
Core plus three saturation sites												
Worst	car23	2015	FEI	F30	F33	F40	-99	90	-99	-99	-99	90
Best	car23	2300	FEI	F31	F33	F40	-99	100	-99	-99	-99	100
Avg	car23	Avg	Avg	--	--	--	-99	99	95	98	97	97
N	car23	N	N	--	--	--	0	286	220	84	120	286
Combinations of two sites (core and saturation)												
Worst	car32	235	F35	F40	--	--	0	2	-99	8	-99	3
Best	car32	325	F38	F39	--	--	-99	100	95	-99	99	98
Avg	car32	Avg	Avg	--	--	--	74	87	89	90	81	84
N	car32	N	N	--	--	--	55	91	78	45	55	91
Combinations of three sites (core and saturation)												
Worst	car33	2237	F28	F35	F40	--	3	56	-99	8	-99	22
Best	car33	2600	F27	F38	F40	--	-99	100	-99	-99	-99	100
Avg	car33	Avg	Avg	--	--	--	88	96	94	97	92	93
N	car33	N	N	--	--	--	165	364	286	120	165	364

Table 35. Population spatial representativeness of the Kern domain (20% criterion) for PMT for the core site and combinations of the core and saturation sites.

	spp56	rank	st1	st2	st3	st4	9	10	11	12	13	14	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	Avg
							Date (December 1995 and January 1996)																									
Single sites																																
Core	pmt00	3	KWR	--	--	--	82	85	90	91	0	77	100	95	100	63	48	4	89	71	90	80	86	72	0	100	30	64	96	100	94	72
Worst	pmt00	1	K17	--	--	--	100	94	7	100	-99	96	96	81	53	9	66	6	84	-99	94	5	77	35	-99	100	7	-99	-99	100	65	64
Best	pmt00	6	K14	--	--	--	100	94	89	100	100	95	99	97	-99	82	-99	-99	2	68	91	87	85	72	30	100	19	67	100	100	60	79
Avg	pmt00	Avg	Avg	--	--	--	93	74	75	98	50	85	85	92	84	65	54	41	74	58	77	71	75	50	60	99	25	54	99	97	63	73
N	pmt00	N	N	--	--	--	6	6	6	5	2	5	6	6	4	6	5	5	6	5	6	6	6	6	5	6	5	5	5	6	6	6
Core plus one saturation site																																
Col	pmt21	1	KWR	K14	--	--	100	96	90	100	100	95	100	97	-99	82	-99	-99	91	71	91	87	86	73	30	100	30	67	100	100	94	85
Worst	pmt21	1	KWR	K14	--	--	100	96	90	100	100	95	100	97	-99	82	-99	-99	91	71	91	87	86	73	30	100	30	67	100	100	94	85
Best	pmt21	5	KWR	K15	--	--	100	100	90	100	-99	97	100	95	100	100	95	50	89	96	90	83	100	72	100	100	-99	66	100	100	100	92
Avg	pmt21	Avg	Avg	--	--	--	100	95	91	100	100	98	100	98	100	83	79	52	90	79	93	85	89	79	76	100	39	69	100	100	96	88
N	pmt21	N	N	--	--	--	5	5	5	4	1	4	5	5	3	5	4	4	5	4	5	5	5	5	4	5	4	4	4	5	5	5
Core plus two saturation sites																																
Worst	pmt22	1	KWR	K13	K14	--	100	96	90	100	-99	100	100	100	-99	82	-99	-99	91	76	99	87	86	73	100	100	30	76	100	100	100	90
Best	pmt22	10	KWR	K15	K17	--	100	100	97	100	-99	100	100	100	100	100	100	56	89	-99	94	88	100	99	-99	100	-99	-99	-99	100	100	96
Avg	pmt22	Avg	Avg	--	--	--	100	99	93	100	-99	99	100	100	100	94	94	73	91	86	95	88	92	85	98	100	48	72	100	100	98	93
N	pmt22	N	N	--	--	--	10	10	10	6	0	6	10	10	3	10	6	6	10	6	10	10	10	10	6	10	6	6	6	10	10	10
Core plus three saturation sites																																
Worst	pmt23	1	KWR	K13	K14	K16	100	96	91	-99	-99	-99	100	100	-99	95	-99	-99	95	76	99	88	86	80	100	100	59	78	100	100	100	92
Best	pmt23	10	KWR	K14	K15	K17	100	100	97	100	-99	100	100	100	-99	100	-99	-99	91	-99	94	92	100	99	-99	100	-99	-99	-99	100	100	98
Avg	pmt23	Avg	Avg	--	--	--	100	100	95	100	-99	100	100	100	100	99	100	79	93	93	97	90	95	91	100	100	57	75	100	100	99	96
N	pmt23	N	N	--	--	--	10	10	10	4	0	4	10	10	1	10	4	4	10	4	10	10	10	10	4	10	4	4	4	10	10	10
Combinations of two sites (core and saturation)																																
Worst	pmt32	1	KWR	K14	--	--	100	96	90	100	100	95	100	97	-99	82	-99	-99	91	71	91	87	86	73	30	100	30	67	100	100	94	85
Best	pmt32	15	K14	K15	--	--	100	98	89	100	-99	97	99	97	-99	100	-99	-99	89	93	91	87	100	73	100	100	-99	67	100	100	100	94
Avg	pmt32	Avg	Avg	--	--	--	100	95	92	100	100	98	100	99	100	89	84	64	90	80	94	87	91	75	89	100	40	70	100	100	89	89
N	pmt32	N	N	--	--	--	15	15	15	10	1	10	15	15	6	15	10	10	15	10	15	15	15	15	10	15	10	10	10	15	15	15
Combinations of three sites (core and saturation)																																
Worst	pmt33	1	KWR	K13	K14	--	100	96	90	100	-99	100	100	100	-99	82	-99	-99	91	76	99	87	86	73	100	100	30	76	100	100	100	90
Best	pmt33	20	K14	K15	K17	--	100	98	96	100	-99	100	100	100	-99	100	-99	-99	89	-99	94	92	100	99	-99	100	-99	-99	-99	100	100	98
Avg	pmt33	Avg	Avg	--	--	--	100	99	94	100	-99	100	100	100	100	96	97	75	92	88	96	89	93	87	99	100	51	73	100	100	97	94
N	pmt33	N	N	--	--	--	20	20	20	10	0	10	20	20	4	20	10	10	20	10	20	20	20	20	10	20	10	10	10	20	20	20

Table 36. Population spatial representativeness of the Kern domain (20% criterion) for CRU for the core site and combinations of the core and saturation sites.

							Date (December 1995 and January 1996)					
	spp56	rank	st1	st2	st3	st4	26	27	4	5	6	Avg
Single sites												
Core site	cru00	3	KWR	--	--	--	100	99	100	49	36	77
Worst	cru00	1	K17	--	--	--	-99	37	-99	100	89	75
Best	cru00	6	K13	--	--	--	100	100	100	97	70	93
Average	cru00	Avg	Avg	--	--	--	100	82	100	79	52	81
N	cru00	N	N	--	--	--	5	6	5	6	6	6
Core plus one saturation site												
Colloc	cru21	3	KWR	K14	--	--	100	99	100	100	49	90
Worst	cru21	1	KWR	K16	--	--	100	100	100	100	36	87
Best	cru21	5	KWR	K13	--	--	100	100	100	100	100	100
Average	cru21	Avg	Avg	--	--	--	100	100	100	90	75	93
N	cru21	N	N	--	--	--	4	5	4	5	5	5
Core plus two saturation sites												
Worst	cru22	1	KWR	K14	K16	--	100	100	100	100	49	90
Best	cru22	10	KWR	K13	K14	--	100	100	100	100	100	100
Average	cru22	Avg	Avg	--	--	--	100	100	100	100	94	99
N	cru22	N	N	--	--	--	6	10	6	10	10	10
Core plus three saturation sites												
Worst	cru23	1	KWR	K13	K14	K16	100	100	100	100	100	100
Best	cru23	10	KWR	K13	K14	K15	100	100	100	100	100	100
Average	cru23	Avg	Avg	--	--	--	100	100	100	100	100	100
N	cru23	N	N	--	--	--	4	10	4	10	10	10
Combinations of two sites (core and saturation)												
Worst	cru32	1	KWR	K16	--	--	100	100	100	100	36	87
Best	cru32	15	KWR	K13	--	--	100	100	100	100	100	100
Average	cru32	Avg	Avg	--	--	--	100	98	100	96	82	95
N	cru32	N	N	--	--	--	10	15	10	15	15	15
Combinations of three sites (core and saturation)												
Worst	cru33	1	KWR	K14	K16	--	100	100	100	100	49	90
Best	cru33	20	KWR	K13	K14	--	100	100	100	100	100	100
Average	cru33	Avg	Avg	--	--	--	100	100	100	100	96	99
N	cru33	N	N	--	--	--	10	20	10	20	20	20

Table 37. Population spatial representativeness of the Kern domain (20% criterion) for SEC for the core site and combinations of the core and saturation sites.

							Date (December 1995 and January 1996)				
	spp56	rank	st1	st2	st3	st4	26	4	5	6	Avg
Single sites											
Core site	sec00	5	KWR	–	–	–	100	100	100	0	75
Worst	sec00	5	KWR	–	–	–	100	100	100	0	75
Best	sec00	6	K15	–	–	–	100	100	100	100	100
Average	sec00	Avg	Avg	–	–	–	100	100	100	50	88
N	sec00	N	N	–	–	–	2	2	2	2	2
Core plus one saturation site											
Worst	sec21	5	KWR	K15	–	–	100	100	100	100	100
Best	sec21	5	KWR	K15	–	–	100	100	100	100	100
Average	sec21	Avg	Avg	–	–	–	100	100	100	100	100
N	sec21	N	N	–	–	–	1	1	1	1	1
Combinations of two sites (core and saturation)											
Worst	sec32	15	KWR	K15	–	–	100	100	100	100	100
Best	sec32	15	KWR	K15	–	–	100	100	100	100	100
Average	sec32	Avg	Avg	–	–	–	100	100	100	100	100
N	sec32	N	N	–	–	–	1	1	1	1	1

Table 38. Population spatial representativeness of the Kern domain (20% criterion) for CAR for the core site and combinations of the core and saturation sites.

							Date (December 1995 and January 1996)				
	spp56	rank	st1	st2	st3	st4	26	4	5	6	Avg
Single sites											
Core site	car00	5	KWR	–	–	–	100	100	0	100	75
Worst	car00	5	KWR	–	–	–	100	100	0	100	75
Best	car00	6	K15	–	–	–	100	100	100	100	100
Average	car00	Avg	Avg	–	–	–	100	100	50	100	88
N	car00	N	N	–	–	–	2	2	2	2	2
Core plus one saturation site											
Worst	car21	5	KWR	K15	–	–	100	100	100	100	100
Best	car21	5	KWR	K15	–	–	100	100	100	100	100
Average	car21	Avg	Avg	–	–	–	100	100	100	100	100
N	car21	N	N	–	–	–	1	1	1	1	1
Combinations of two sites (core and saturation)											
Worst	car32	15	KWR	K15	–	–	100	100	100	100	100
Best	car32	15	KWR	K15	–	–	100	100	100	100	100
Average	car32	Avg	Avg	–	–	–	100	100	100	100	100
N	car32	N	N	–	–	–	1	1	1	1	1

Table 39. Population spatial representativeness of the Bakersfield domain (20% criterion) for PMT for the core site and combinations of the core and saturation sites.

							Date (December 1995 and January 1996)																									
	spp56	rank	st1	st2	st3	st4	9	10	11	12	13	14	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	Avg
Single sites																																
Core	pmt00	5	BFK	--	--	--	96	54	88	0	32	79	88	100	5	95	6	5	25	1	92	95	99	52	51	30	80	48	99	77	99	60
Worst	pmt00	1	B08	--	--	--	88	9	0	1	2	77	90	100	1	0	1	28	0	2	1	-99	1	-99	-99	1	1	0	91	8	1	23
Best	pmt00	13	B07	--	--	--	1	89	97	86	60	0	-99	100	100	93	78	60	78	52	97	100	69	94	90	-99	80	21	99	94	97	75
Avg	pmt00	Avg	Avg	--	--	--	67	46	80	37	33	54	73	84	82	81	29	18	29	44	78	83	85	61	59	41	58	36	91	56	83	60
N	pmt00	N	N	--	--	--	13	13	13	10	12	11	12	13	13	13	13	12	13	11	13	11	13	12	11	12	13	11	13	13	12	13
Core plus one saturation site																																
Colloc	pmt21	2	BFK	B01	--	--	98	61	92	-99	32	-99	88	100	100	95	15	17	69	30	94	-99	99	52	97	30	81	50	99	77	99	72
Colloc	pmt21	5	BFK	B12	--	--	97	56	98	45	34	-99	88	100	100	95	39	5	25	94	97	95	99	52	97	91	80	48	99	77	99	75
Worst	pmt21	1	BFK	B08	--	--	98	63	88	1	34	97	95	100	5	95	7	33	25	3	93	-99	99	-99	-99	31	81	48	100	85	100	63
Best	pmt21	12	BFK	B07	--	--	97	89	97	86	92	79	-99	100	100	95	84	65	83	52	99	100	99	95	93	-99	80	48	99	94	99	88
Avg	pmt21	Avg	Avg	--	--	--	97	67	93	41	56	90	91	100	90	96	35	23	47	48	96	98	99	76	84	58	82	64	99	84	99	77
N	pmt21	N	N	--	--	--	12	12	12	9	11	10	11	12	12	12	12	11	12	10	12	10	12	11	10	11	12	10	12	12	11	12
Core plus two saturation sites																																
Colloc	pmt22	8	BFK	B01	B12	--	99	63	98	-99	34	-99	88	100	100	95	48	17	69	98	97	-99	99	52	97	91	81	50	99	77	99	80
Worst	pmt22	1	BFK	B01	B08	--	98	63	92	-99	34	-99	95	100	100	95	16	45	69	32	95	-99	99	-99	-99	31	82	50	100	85	100	74
Best	pmt22	66	BFK	B07	B10	--	98	89	98	92	93	98	-99	100	100	95	88	74	97	86	99	100	99	98	97	-99	82	93	99	97	99	94
Avg	pmt22	Avg	Avg	--	--	--	98	77	96	67	73	95	93	100	100	97	57	37	64	73	98	99	99	87	95	76	84	76	99	90	99	86
N	pmt22	N	N	--	--	--	66	66	66	36	55	45	55	66	66	66	66	55	66	45	66	45	66	55	45	55	66	45	66	66	55	66
Core plus three saturation sites																																
Worst	pmt23	1	BFK	B01	B04	B08	98	63	92	-99	34	-99	95	100	100	99	16	47	94	32	95	-99	99	-99	-99	58	93	51	100	88	100	78
Best	pmt23	220	BFK	B05	B06	B07	98	96	99	96	99	99	-99	100	100	96	97	-99	87	100	100	100	99	99	95	-99	81	98	100	100	100	97
Avg	pmt23	Avg	Avg	--	--	--	99	84	97	82	84	97	94	100	100	97	72	49	77	87	99	100	99	93	98	87	85	84	100	93	100	91
N	pmt23	N	N	--	--	--	220	220	220	84	165	120	165	220	220	220	220	165	220	120	220	120	220	165	120	165	220	120	220	220	165	220
Combinations of two sites (core and saturation)																																
Worst	pmt32	1	B05	B08	--	--	99	9	46	86	83	82	95	100	81	96	52	30	4	9	64	-99	74	-99	-99	15	67	50	100	14	50	59
Best	pmt32	78	B07	B11	--	--	96	89	97	87	97	79	-99	100	100	97	84	69	81	-99	99	100	99	95	93	-99	80	74	99	94	-99	91
Avg	pmt32	Avg	Avg	--	--	--	90	68	95	61	57	79	89	98	98	95	50	33	51	69	95	97	97	83	83	67	77	60	99	80	97	79
N	pmt32	N	N	--	--	--	78	78	78	45	66	55	66	78	78	78	78	66	78	55	78	55	78	66	55	66	78	55	78	78	66	78
Combinations of three sites (core and saturation)																																
Worst	pmt33	1	B01	B04	B08	--	89	9	92	-99	15	-99	95	100	100	99	12	47	93	32	95	-99	98	-99	-99	58	93	9	100	88	95	71
Best	pmt33	286	B02	B06	B09	--	97	92	98	-99	99	99	96	100	100	99	88	-99	88	100	100	100	97	95	-99	96	77	-99	100	90	99	96
Avg	pmt33	Avg	Avg	--	--	--	96	80	97	77	74	90	93	100	100	97	66	45	67	83	98	99	99	91	92	82	83	75	99	90	99	88
N	pmt33	N	N	--	--	--	286	286	286	120	220	165	220	286	286	286	286	220	286	165	286	165	286	220	165	220	286	165	286	286	220	286

Table 40. Population spatial representativeness of the Bakersfield domain (20% criterion) for CRU for the core site and combinations of the core and saturation sites.

							Date (December 1995 and January 1996)					
	spp56	rank	st1	st2	st3	st4	26	27	4	5	6	Avg
Single sites												
Core site	cru00	11	BFK	--	--	--	84	49	78	76	70	71
Worst	cru00	1	B08	--	--	--	0	0	1	0	0	0
Best	cru00	13	B11	--	--	--	-99	63	74	83	-99	74
Average	cru00	Avg	Avg	--	--	--	42	53	61	43	49	50
N	cru00	N	N	--	--	--	11	13	13	13	12	13
Core plus one saturation site												
Colloc	cru21	5	BFK	B01	--	--	90	49	80	89	82	78
Colloc	cru21	11	BFK	B12	--	--	99	96	98	88	70	90
Worst	cru21	1	BFK	B08	--	--	84	49	79	76	71	72
Best	cru21	12	BFK	B02	--	--	99	99	98	91	70	91
Average	cru21	Avg	Avg	--	--	--	90	75	88	82	81	83
N	cru21	N	N	--	--	--	10	12	12	12	11	12
Core plus two saturation sites												
Colloc	cru22	42	BFK	B01	B12	--	99	96	98	89	82	93
Worst	cru22	1	BFK	B06	B08	--	92	50	79	77	77	75
Best	cru22	66	BFK	B02	B03	--	-99	99	99	94	99	98
Average	cru22	Avg	Avg	--	--	--	94	88	93	87	88	90
N	cru22	N	N	--	--	--	45	66	66	66	55	66
Core plus three saturation sites												
Worst	cru23	1	BFK	B06	B08	B11	-99	64	79	88	-99	77
Best	cru23	220	BFK	B02	B03	B05	-99	99	99	96	99	98
Average	cru23	Avg	Avg	--	--	--	97	95	96	90	93	94
N	cru23	N	N	--	--	--	120	220	220	220	165	220
Combinations of two sites (core and saturation)												
Worst	cru32	1	B06	B08	--	--	8	7	1	1	6	5
Best	cru32	78	B03	B12	--	--	-99	97	99	91	99	96
Average	cru32	Avg	Avg	--	--	--	68	79	85	68	75	76
N	cru32	N	N	--	--	--	55	78	78	78	66	78
Combinations of three sites (core and saturation)												
Worst	cru33	1	B03	B06	B08	--	-99	19	20	47	55	35
Best	cru33	286	B02	B05	B07	--	99	99	95	96	99	98
Average	cru33	Avg	Avg	--	--	--	84	91	93	81	87	88
N	cru33	N	N	--	--	--	165	286	286	286	220	286

Table 41. Population spatial representativeness of the Bakersfield domain (20% criterion) for SEC for the core site and combinations of the core and saturation sites.

	spp56	rank	st1	st2	st3	st4	26	27	4	5	6	Avg
							Date (December 1995 and January 1996)					
Single sites												
Core site	sec00	12	BFK	--	--	--	100	95	99	99	100	99
Worst	sec00	6	B12	--	--	--	100	8	32	100	100	68
Best	sec00	13	B01	--	--	--	100	98	-99	98	-99	99
Average	sec00	Avg	Avg	--	--	--	100	72	75	87	100	87
N	sec00	N	N	--	--	--	8	8	7	8	5	8
Core plus one saturation site												
Colloc	sec21	11	BFK	B01	--	--	100	98	-99	99	-99	99
Colloc	sec21	12	BFK	B12	--	--	100	100	99	100	100	100
Worst	sec21	6	BFK	B04	--	--	100	95	99	99	-99	98
Best	sec21	12	BFK	B12	--	--	100	100	99	100	100	100
Average	sec21	Avg	Avg	--	--	--	100	97	100	99	100	99
N	sec21	N	N	--	--	--	7	7	6	7	4	7
Core plus two saturation sites												
Colloc	sec22	64	BFK	B01	B12	--	100	100	-99	100	-99	100
Worst	sec22	46	BFK	B04	B07	--	100	96	99	99	-99	98
Best	sec22	66	BFK	B10	B12	--	100	100	100	100	100	100
Average	sec22	Avg	Avg	--	--	--	100	98	100	100	100	99
N	sec22	N	N	--	--	--	21	21	15	21	6	21
Core plus three saturation sites												
Worst	sec23	186	BFK	B04	B07	B09	100	96	99	100	-99	99
Best	sec23	220	BFK	B09	B10	B12	100	100	100	100	100	100
Average	sec23	Avg	Avg	--	--	--	100	99	100	100	100	100
N	sec23	N	N	--	--	--	35	35	20	35	4	35
Combinations of two sites (core and saturation)												
Worst	sec32	51	B07	B12	--	--	100	8	44	100	100	70
Best	sec32	78	B10	B12	--	--	100	100	100	100	100	100
Average	sec32	Avg	Avg	--	--	--	100	93	95	99	100	98
N	sec32	N	N	--	--	--	28	28	21	28	10	28
Combinations of three sites (core and saturation)												
Worst	sec33	231	B04	B07	B09	--	100	93	96	100	-99	97
Best	sec33	286	B09	B10	B12	--	100	100	100	100	100	100
Average	sec33	Avg	Avg	--	--	--	100	98	99	100	100	99
N	sec33	N	N	--	--	--	56	56	35	56	10	56

Table 42. Population spatial representativeness of the Bakersfield domain (20% criterion) for CAR for the core site and combinations of the core and saturation sites.

	spp56	rank	st1	st2	st3	st4	26	27	4	5	6	Avg
							Date (December 1995 and January 1996)					
Single sites												
Core site	car00	10	BFK	--	--	--	58	43	82	42	41	53
Worst	car00	6	B05	--	--	--	9	39	9	3	-99	15
Best	car00	13	B09	--	--	--	39	74	85	62	89	70
Average	car00	Avg	Avg	--	--	--	58	51	48	35	46	46
N	car00	N	N	--	--	--	8	8	8	8	5	8
Core plus one saturation site												
Colloc	car21	7	BFK	B01	--	--	58	54	82	42	-99	59
Colloc	car21	8	BFK	B12	--	--	90	96	83	42	41	70
Worst	car21	6	BFK	B04	--	--	58	43	93	42	-99	59
Best	car21	12	BFK	B09	--	--	97	100	90	90	90	93
Average	car21	Avg	Avg	--	--	--	81	74	88	58	61	72
N	car21	N	N	--	--	--	7	7	7	7	4	7
Core plus two saturation sites												
Colloc	car22	49	BFK	B01	B12	--	90	96	83	42	-99	78
Worst	car22	46	BFK	B01	B04	--	58	54	93	42	-99	62
Best	car22	66	BFK	B09	B10	--	100	100	97	99	94	98
Average	car22	Avg	Avg	--	--	--	93	90	92	71	76	85
N	car22	N	N	--	--	--	21	21	21	21	6	21
Core plus three saturation sites												
Worst	car23	186	BFK	B01	B04	B05	67	93	100	45	-99	76
Best	car23	220	BFK	B04	B09	B10	100	100	100	99	-99	100
Average	car23	Avg	Avg	--	--	--	98	97	95	81	87	93
N	car23	N	N	--	--	--	35	35	35	35	4	35
Combinations of two sites (core and saturation)												
Worst	car32	51	B04	B05	--	--	41	49	59	21	-99	43
Best	car32	78	B09	B12	--	--	100	98	91	90	90	94
Average	car32	Avg	Avg	--	--	--	84	79	75	59	68	73
N	car32	N	N	--	--	--	28	28	28	28	10	28
Combinations of three sites (core and saturation)												
Worst	car33	231	B01	B04	B05	--	63	93	59	30	-99	61
Best	car33	286	B04	B07	B10	--	99	100	100	99	-99	99
Average	car33	Avg	Avg	--	--	--	95	92	89	75	80	87
N	car33	N	N	--	--	--	56	56	56	56	10	56

The core sites alone achieved a PR of 90 percent or greater for PM mass at Corcoran and secondary sepecies at Bakersfield and Fresno (Table 43). For PM mass in Bakersfield and Fresno, the network would have over 90% representativeness with just the core site and two other sites. For all other cases, PR exceeding 90% is achieved by supplementing the core site with one other site (Table 43). Since the best supplementary site, or sites, varies among components (PM mass, CRU, CAR, and SEC), in some cases three supplementary sites would be needed to ensure that not only PM mass but also the concentrations each of the species groups achieved a representativeness exceeding 90 percent.

Table 43. Additional sites required along with core site to most effectively achieve a PR of 90% or greater in each of four networks.

SITE	SPECIES			
	PM	CRU	SEC	CAR
Corcoran	none*	C06	C13	C09
Bakersfield	B07, B10	B02	none*	B09
Fresno	F19, F25	F40** or F27, F32	none*	F39
Kern	K15	K13	***	***

* The core site alone has a PR of 90 percent or greater.
** The combination FEI-F40 had only two days data. The next best was FEI-F27-F32.
*** Only two sites had the necessary measurements.

Based on PR as displayed in Tables 27-42, the four core sites are appropriately located so as to represent average concentrations. The PR of the core site plus the best second site (or third, if required to achieve 90%) in each network is within 2 percentage points of the PR of any other combination of two or three sites, in all but two cases. In those two cases, the PR of the core site plus one other site was within either 3 or 5 percentage points of the PR of the best alternative pair of sites. This result is consistent with the simple observation that, for each network, the core site's concentrations are close to the median over all sites (see Section 2).

The preceding discussion also applies to the computation of outdoor exposure estimates (indoor exposure was not addressed in this study). As indicated, the core site plus one or two additional sites in each of the Fresno, Bakersfield, and Corcoran areas would yield population exposure estimates close to those that could be obtained from the full networks, since the PR of the core plus two sites, chosen as indicated, exceeded 90 percent.

In contrast, core sites do not always represent the network maxima. In Corcoran, site C05 exhibited substantially greater PM mass concentrations than did the core site, by up to 130 $\mu g\ m^{-3}$ (see Section 2). In Bakersfield and Fresno, area maxima often occurred at sites within one to two km of the core sites. However, the differences in concentration between the core and the maximum sites were less than 5 $\mu g\ m^{-3}$ on average.

CONCLUSION

The spatial representativeness of a site may be defined in various ways. The definition used here is the percentage of the area of a saturation monitoring domain having concentrations within 20 percent of those recorded at the site under consideration. Population representativeness was defined as the percentage of domain population in areas having concentrations within 20 percent of those recorded at the site under consideration. The choice of 20 percent was based upon consideration of differences that would be expected to be judged significant from a health-effects perspective, the variation of concentrations across monitoring sites, measurement uncertainty, and an analysis of the sensitivity of the findings. Typically, PM concentrations varied across sites by about 50 percent on any day while sampling uncertainty for PM_{10} mass was about 10 $\mu g\ m^{-3}$ (see Section 2), corresponding to about 10 to 20 percent of the typical mass concentrations recorded in the Fresno and Bakersfield areas.

To determine spatial representativeness, the monitoring data were interpolated to fine (0.1 km) grids for both the fall and winter saturation networks. The species analyzed were PM_{10} mass, the secondary component (sum of sulfate, nitrate, and ammonium), carbon (elemental plus organic), and the crustal component (the sum of aluminum, silicon, iron, manganese, calcium, and magnesium). The gridded values were then used to determine the portions of the monitoring domains having values within the specified percentage of those recorded at each individual site.

Spatial representativeness varied considerably among sites, days, and components. Averaging across days, the mean areal fractions of the saturation domains having PM_{10} concentrations within 20 percent of those recorded at the core sites were 65% for Bakersfield, 87% for Corcoran, 44% for Fresno, and 79% for Kern. Population representativeness was always slightly greater or approximately equal to area representativeness. Monitoring sites generally had greater areas of representativeness for secondary species than for PM10 mass, and lesser areas for crustal and carbon components.

It was shown that at least 90 percent of each saturation monitoring domain would exhibit concentrations within 20 percent of those of the core site plus one or two additional sites. The most representative combinations of two to three sites were identified for each domain. While the core sites were shown to represent average domain concentrations well, they did not always represent the network maxima. In Corcoran, the maximum site exhibited PM mass concentrations up to 130 $\mu g\ m^{-3}$ greater than those of the core site. In Bakersfield and Fresno, the differences in concentration between the core and the maximum sites were less than 5 $\mu g\ m^{-3}$ on average.